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INTERRELATIONSHIPS Among Five Cotton-Quality Factors, Including Fiber Strength 1/8-Inch Vs. 0 Gauge, as Related to Yarn Strength at Three Staple-Length Levels

Marketing Research Report No. 684

U. S. DEPARTMENT OF AGRICULTURE Agricultural Research Service

PREFACE

In every blend or mix of cottons used in textile processing, the existing fiber-property interrelationships constitute a jumbled and variable complex. And, with increasing numbers of cottons, wider ranges in fiber properties, and more fiber measures represented in the analysis, the larger is the number and the greater is the complexity of the factorial interrelationships and effects contributing to the resulting correlation values. As a result of this, plus limitations in analytical methods heretofore available and used, the influences of individual and group fiber-measure interrelationships on cotton spinning performance and yarn quality are unknown today.

This new study—by its nature, scope, and method of approach—is viewed as a very significant one in reference to cotton quality evaluations. The results from it should go a long way toward clearing up various questions involved in the interrelationships connected with the Pressley fiber strength measures, ⅛-inch gauge versus 0 gauge, as they influence evaluations of explainable yarn-strength variance. This study, moreover, may well serve as a prototype for similar studies needed along many other lines of cotton-quality evaluations.

Presented and discussed in this report are findings obtained from a pioneering investigation made to explore, disentangle, and demonstrate the role of interrelationships identified with certain cotton fiber measures; and to point the way for making cotton quality evaluations more objective, more reliable, and more meaningful in the future than they are at the present time.

The findings reported herein should be of special interest to cotton breeders, textile manufacturers, inventors and designers of cotton fiber testing instruments, and all persons engaged in research, testing, and evaluations with respect to cotton quality.

This area of research constitutes an important discipline of modern cotton fiber technology and represents a specialized phase of cotton quality about which relatively little is known. The most revealing information obtained from this study was derived by application of a series of analytical procedures developed expressly for the purpose.

Basically, this method involves a coupling and weighting of certain statistical values obtained from conventional multiple and simple correlation analyses, due regard to all signs involved. The technique includes several unique features which, insofar as known, go beyond traditional practices.

The statistical and mathematical basis for the reported interpretations appears to be sound in theory, principle, and application, as confirmed by results obtained for far-removed subjects from pioneering studies made 40 or more years ago by other investigators. Those early publications are apparently unknown to or have been forgotten by most persons doing cotton-quality research and testing today.

These new results extend the borders of knowledge in reference to the meaning of some cotton-fiber measures and certain correlation measures, and they provide a basis for promoting a better understanding of the following: (1) The contribution which certain cotton fiber measure interrelationships make in terms of explainable yarn-strength variance and (2) the effect of those interrelationships on various values derived from multiple and simple correlation analyses in reference to yarn strength. These findings suggest a new emphasis, if not a new dimension, in thinking, concepts, and procedures basic to the development of more accurate, comprehensive, and meaningful evaluations with respect to cotton fiber quality.

The effects of the interactions between various pairs of cotton-fiber measures on explainable yarn-strength variance are shown to be important and, in some cases, more enlightening than the effects of the fiber measures acting independently. While the principal net effects of the individual fiber measures can be evaluated and predicted rather easily, their interactional effects are more complicated to evaluate and less susceptible to prediction. Evaluations of the interactional effects, however, provide a deeper insight into and a fuller characterization of cotton-fiber properties, cotton-fiber measures, and processing qualities of cotton fibers than can be obtained without them.

These findings furnish a basis for explaining many inconsistencies noted in correlation results with cotton fibers and yarn strength over the years, disparities of which have perplexed cotton and textile technologists many times as to their cause or causes.

These results also indicate why the values obtained for partial correlation coefficients with yarn strength, representing most series of cottons, are larger in magnitude than those for corresponding beta coefficients; why they are approximately the same under some conditions; and why partial correlation values are, and properly should be, smaller than corresponding beta values under certain conditions.

This report includes correlation values for six sets of analytical conditions identified with skein strength of 22s carded yarn spun from American upland cottons, representing three staple-length levels.

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ACKNOWLEDGMENT

Appreciation is expressed to Gordon L. Austin, former staff member who is now retired, for being responsible for all the correlation analyses involved in this study; to Preston LaFerney, Economics Research Service, for references to early publications dealing with multiple correlation analysis and for valuable suggestions concerning the form and interpretation of pertinent mathematical formulae; and to Franklin E. Newton and others for helpful assistance in revising the manuscript for publication.

Washington, D.C. Issued May 1965

SUMMARY AND CONCLUSIONS

Five factors of raw cotton quality, including the alternative fiber strength measures of ⅛-inch gauge and 0 gauge as determined by the Pressley flat-bundle test method, were used in parallel sets of multiple and simple correlation analyses with skein strength of 22s carded yarn, representing each of three series of American upland cottons of different staple-length levels, crop years 1954–57. The cottons originated from known varieties grown in their respective production areas of the U.S. Cotton Belt. The other quality factors included in the analyses were upper half mean length, length uniformity ratio, micronaire reading, and grade index.

A pronounced upward trend in values was obtained for the total interactions and residuals ($\overline{R}^2 \times 100$—sum of 5 individual $\text{beta}^2 \times 100$) when each of the two groups of fiber measures was correlated with strength of 22s yarn spun from cottons of increasing staple-length level. With the five factors, including fiber strength at the ⅛-inch gauge, the respective values for the short-staple, medium-staple, and long-staple upland cottons were as follows: −0.61, +14.29, +40.30 percent units of explainable yarn-strength variance. With the five factors, including fiber strength at the 0 gauge, the corresponding values were −19.79, −0.93, +33.97 percent units of explainable yarn-strength variance.

Thus, the values for total interactions and residuals from analyses with fiber strength at the ⅛-inch gauge were on a distinctly higher level than those with fiber strength at the 0 gauge. Those differences, however, decreased in magnitude with increasing staple-length level of the cottons represented, as shown by the respective values of +19.18, +15.22, +6.33 percent units of explainable yarn-strength variance.

Most of the total interactions and residuals identified with the alternative groups of five fiber measures in correlation with yarn strength has been explained in terms of yarn-strength variance, as estimated on the basis of the net sum of positive and negative effects arising from the 10 possible pairs of fiber-measure interrelationships involved in each analysis.

Estimated values of explainable yarn-strength variance also have been derived for each series of cottons with respect to interrelational effects, as follows: Four pairs of fiber measures identified with fiber strength at the ⅛-inch gauge, four pairs of measures associated with fiber strength at the 0 gauge, and six pairs of measures independent of the fiber strength measures.

In terms of estimated yarn-strength variance explained by the fiber-measure interrelationships, it is concluded that fiber strength at the ⅛-inch gauge was a relatively "pure" measure of fiber strength with the short staple cottons but that it was a complex of increasing proportions, in the positive direction toward yarn strength, with the medium staple cottons and with the long staple cottons. The estimated interrelational effects associated with fiber strength at the ⅛-inch gauge were +1.01 percent for the short, +16.16 for the medium, and +39.70 for the long cottons.

Within the framework of the same definition, by contrast, it is concluded that fiber strength at the 0 gauge was a relatively "pure" measure of fiber strength for the cottons of medium staple length but that it showed a moderate amount of interrelational effects in the negative direction toward yarn strength with the short staple cottons and about the same amount in the positive direction with the long staple cottons. The estimated interrelational effects connected with fiber strength at the 0 gauge were −13.98 percent for the short, +0.66 for the medium, and +13.73 for the long cottons.

For the long staple series of cottons, the amount of yarn-strength variance explained by the interrelationships identified with fiber strength at the ⅛-inch gauge was estimated to be approximately three times that of those associated with fiber strength at the 0 gauge. The comparative estimates were +39.70 and +13.73 percent. Thus, it is concluded that fiber strength at the 0 gauge was a "purer" measure of fiber strength with these long staple cottons than was fiber strength at the ⅛-inch gauge.

The six pairs of fiber-measure interrelationships independent of the two fiber strength measures showed practically no effect toward yarn-strength variance with the cottons of medium staple length, only a small negative effect with the short staple cottons, and a positive effect of about twice the latter amount with the long staple cottons. The means of the two comparative sets of estimated interrelational effects independent of the two fiber strength measures were −4.36 percent for the short, +0.16 for the medium, and +8.36 for the long cottons.

The interpretations and conclusions stated above for the interrelational effects of these cotton fiber measures in terms of explainable yarn-strength variance neither apply to nor represent any other dependent variable of product quality. Rather, for a given combination of quality factors

and group of cottons, their interrelational effects would be expected to vary more or less with each factor of product quality.

An outgrowth of particular interest from this study is the fiber-strength ratio value (⅛-inch/0) per sample of cotton. Some possibilities are disclosed in this report which indicate that this ratio may prove to be a promising new target and criterion of cotton quality for assistance to breeders in their continuing efforts to improve the fiber properties of American cotton, and to textile manufacturers in their competitive efforts to improve the comparative strength of their processed yarns.

The evidence presented in this report strongly suggests that cotton fiber measures also need to be evaluated and standardized in terms of some of their interrelational effects, at least as regards yarn-strength variance representing cottons of different staple-length levels. This additional calibration is especially needed for the alternative measures of any cotton fiber property, if their respective meanings, comparative significance, and relative merits are to be precisely known and fully appreciated. Evaluation of cotton fiber-test methods by results only from simple and general analyses is not good enough for present and future challenges and opportunities.

Interrelationships Among Five Cotton-Quality Factors, Including Fiber Strength 1/8-Inch Vs. 0 Gauge, as Related, to Yarn Strength at Three Staple-Length Levels

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INTRODUCTION

Interrelationships may occur in positive or negative directions and usually exist in varying degrees between all possible pairs of fiber measures used in evaluating the quality of cotton, or that of a series of cottons. Those intricate and generally obscure factorial interrelationships individually and collectively influence more or less the magnitude of all values obtained from multiple correlation analyses relating cotton fiber properties to yarn strength, or to yarn appearance, or to any other dependent variable. When 5 quality factors are used, a total of 10 possible pairs of fiber-measure interrelationships is involved; for 6 factors, the total is 15 pairs; for 7 factors, the total is 21 pairs; and so on. Thus, the precise evaluation of cotton quality and of the relative net contribution of each fiber property or measure to a dependent variable becomes increasingly complex with increasing number of factors included in the correlation analysis.

Some of the pairs of cotton fiber-measure interrelationships involved in a correlation analysis exert an appreciable positive effect on explainable yarn-strength variance; some pairs exert a sizable negative effect; and still other pairs may exert little or no detectable effect. The total net effect on explainable yarn-strength variance arising from the fiber-measure interrelationships involved in a correlation analysis, therefore, represents the sum of all the respective positive and negative effects present. This total net effect, moreover, is influenced by the number and combination of fiber measures included in the correlation analysis and also by the level, distribution, and range of fiber-measure values and yarn-strength data represented.

As determined by the Pressley flat-bundle test method, cotton fiber strength at the 1/8-inch gauge generally has shown a higher degree of correlation with yarn strength and usually possesses more evaluated importance to yarn strength than does cotton fiber strength at the 0 gauge. Such differential evaluations over the years with respect to a fiber property are disturbing and disconcerting in terms of meaning and cause or causes for them. But, worse than that, the magnitude of the evaluated importance of fiber length and of fiber fineness toward yarn strength for a series of cottons frequently has been found to vary more or less, depending on whether fiber strength at the 1/8-inch gauge or at the 0 gauge was used in the correlation analysis. In particular, when fiber strength at the 1/8-inch gauge has been included in the correlation analysis for a series of cottons, the evaluated importance of upper half mean length and of micronaire readings (fiber fineness and maturity in combination) toward yarn strength generally has been found to be less than when fiber strength at the 0 gauge was included in the parallel analysis for the same series of cottons.

Further, when the respective fiber strength measures of 1/8-inch gauge and 0 gauge have accompanied the same group of additional fiber measures in parallel multiple correlation analyses with yarn strength, representing different series of cottons, sometimes the coefficients or multiple determination ($\bar{R}^2 \times 100$) have been found to be relatively wide apart, sometimes to differ only moderately, and sometimes even to be practically identical. The standard errors of estimate ($\bar{S}$), as identified with the respective regression equations representing those alternative groups of fiber measures, also have been observed to vary in similar manner and degree.

Therefore, in the light of all the inconsistencies and disparities cited in the foregoing for findings obtained from past correlation analyses using cotton fiber measures and yarn strength, important questions arise as to the nature and scope of the cause or causes which were responsible for them. Those questions, however, involve a host of complex features and effects, by reason of the fact that so many possible factors are operating directly and indirectly, some in positive and others in negative directions, and with varying degrees of cumulative and compensative effects. Also, there always is the possibility of some limiting factor being present within or outside the experimental system which is capable of exerting

an influence or effect, in disguise, to the extent of masking the true cause-and-effect relations involved and of causing erroneous, if not sometimes misleading, evaluations and conclusions to be reported for them.

Today, nobody knows the precise answers to the questions raised and suggested in the foregoing with respect to cotton-quality evaluations and, in the absence of proper data, nobody is able to advance any very constructive speculations on them. A careful and extensive search of the published literature on cotton over the years, moreover, reveals no contributions along these lines of any particular consequence or significance. And, insofar as it is known, no analyses and studies focused primarily on these cotton fiber questions are being conducted today, in any comprehensive manner, at any other institution in this country.

Nevertheless, research and testing cotton technologists, laboratory analysts, various instrumentational specialists, cotton breeders, technical workers in the textile industry, and others need to know the answers to all such questions as quickly and completely as possible. Those workers need such information for assistance in better meeting their responsibilities and objectives of a current and practical nature and, also, for stimulating their thinking and perspective toward making constructive progress and rapid advances in the future. Information of this kind is long overdue in development and even now it is emerging only slowly and tediously from the concerted effort that has been applied in this study over the past 5 years.

This broad study of an exploratory and pioneering nature involves a number of different phases, only one aspect of which is covered in this report. The study was made in an effort to develop a comprehensive body of information that would be useful in pointing the way and providing a basis for making needed improvements in technical and statistical thinking, concepts, and procedures, whereby cotton fiber measurements and their evaluations may be made more objective, more reliable, and more meaningful in the future than they are at the present time. In particular, effort has been made in this study to diagnose and evaluate various interrelationships among certain fiber measures when applied to commercial cottons and to explain their contributing and complicating effects on conventional evaluations currently being made as to the relations of cotton fiber measures to yarn strength and to yarn appearance.

This report, the first in a proposed group, includes the principal findings obtained from a systematic series of multiple and simple correlation analyses involving five cotton fiber measures, including the alternative fiber strength measures of ⅛-inch gauge and 0 gauge, with skein strength of 22s carded yarn, representing short staple, medium staple, and long staple American upland cottons from the crops of 1954–57. Values from the respective analyses have been coupled and linked together in a manner and to an extent that never before has been done, and apparently to good advantage. Strong and consistent evidence is presented in this report on various phases of cotton-quality evaluations and correlation results, including some heretofore moot and baffling questions. The information reported herein explains in substantial part many of the inconsistencies and disparities noted in correlation results with cotton fibers and their yarn strength during previous years.

HISTORICAL REVIEW OF LITERATURE

Interrelationships between cotton fiber properties undergo changes in various ways and degrees all the time, and they will continue to change more or less as long as cotton is grown, aided by nature and by the designed efforts of cotton breeders through the processes of genetics and breeding and through the crosses and selections which they develop.

Cotton Fiber Measure Interrelationships, Crop Years 1935–37

In the late 1930's, when the writer and his associates first began making correlation analyses in their effort to evaluate the relations of cotton fiber measures to yarn strength and to other yarn-quality factors, perplexing questions immediately arose as to the influence which the interrelationships between the fiber properties and between the fiber measures might exert on the end results from correlation analyses, what to do about their complicating effects on values obtained from conventional correlation analyses, and how to cope with them. The first large body of data on cotton fibers, processing, and yarns to become available in the United States for this purpose was obtained in connection with the Federal-State South-wide regional variety study, representing 16 leading varieties of American upland cotton in commercial production at that time, grown in duplicate plots at eight geographical locations throughout the rainfall part of the American Cotton Belt, for the 3 crop years 1935–37.

A total of 768 individual samples became available from that project and the respective averages of data for the 384 pairs of samples representing the combined short staple, medium staple, and long staple upland cottons were used in an overall mixed series for the correlation analyses which followed. The data represented the following eight growth locations: Florence, S.C.; Stoneville, Miss.; Marianna (Upland Station), Ark.; Marianna (Delta Station), Ark.; Baton Rouge, La.; Stillwater, Okla.; College Station, Tex.; and Lubbock, Tex. The following 16 pure and formerly widely grown varieties of cotton were represented:

Acala (Rogers)	Deltapine 11
Arkansas 17	Dixie Triumph 759
Cleveland (Wannamaker)	Farm Relief 2
Cook 912	Half and Half
Delfos (Misdell) 4	Mexican Big Boll
Qualla	Stoneville 5
Rowden 40–2088	Triumph (Oklahoma) 44
Startex 619	Wilds 5

As reported in 1945 by Webb and Richardson (*31*),[1] using the data described in the foregoing, a study was first made of the simple correlations between the 15 possible pairs of 6 fiber measures $\left(\frac{6\times5}{2}\right)$. The raw-cotton quality factors used in those analyses were: Sorter upper quartile length, coefficient of length variability, fiber weight per inch (fineness), Chandler wrapped round-bundle strength (0 gauge), percentage of mature fibers, and grade number (classification). Tabulated below are the findings that were obtained, the paired factors being listed in order of descending values for the respective coefficients of simple correlation:

Rank	*Fiber measures correlated*	*Coefficients of correlation (r)*[1]
(1)	Grade with coefficient of length variability	+0.627
(2)	Fiber weight per inch with percent of mature fibers	+.611
(3)	Upper quartile length with fiber weight per inch	—.603
(4)	Coefficient of length variability with percent of mature fibers	—.572
(5)	Fiber weight per inch with (C) fiber strength	—.426
(6)	Coefficient of length variability with fiber weight per inch	—.377
(7)	Grade with percent of mature fibers	—.321
(8)	Percent of mature fibers with (C) fiber strength	—.287
(9)	Grade with upper quartile length	—.225
(10)	Grade with fiber weight per inch	—.225
(11)	Upper quartile length with coefficient of length variability	—.120*
(12)	Upper quartile length with (C) fiber strength	+.089*
(13)	Coefficient of length variability with (C) fiber strength	+.088*
(14)	Upper quartile length with percent of mature fibers	—.058*
(15)	Grade with (C) fiber strength	+.034*

[1] The sign indicates the direction of the relationship between the respective pairs of factors.
*Statistically insignificant, being less than 3 times its standard error.

The foregoing values, even though they were obtained about 25 years ago, possess special interest at the present time despite the fact that: (1) most of those fiber tests have been supplanted by new and more rapid tests, (2) practically all of those varieties of cotton have disappeared from commercial production, and (3) the fiber-measure interrelationships of those cottons likely were different in a number of particulars from those of present day cottons. Those fiber-measure associations, moreover, were of special interest at the time to cotton breeders who wished to know whether an improvement in one fiber property is likely to be accompanied by an improvement or a deterioration in some other fiber property.

Scatter diagrams, representing the data for each of the 15 pairs of fiber measures, revealed a wide scatter for all the pairs and indicated a linear trend in every instance. No suggestion of a curvilinear relationship was observed with any of the pairs of fiber measures, as based on the wide ranges of data involved which represented the 16 combined varieties of American upland cotton included.

In this connection, it should be remembered that simple correlations between various pairs of cotton fiber properties are affected somewhat by the fact that several fiber properties generally are correlated with or interacting upon each other. Thus, coefficients of simple correlation should be looked upon, in such instances, as referring more particularly to the apparent relationships existing between the various pairs of fiber properties rather than to the true relationships occurring between them. Although the reported coefficients of simple correlation possess limitations, they are of interest in that they suggest what to expect when any two of the fiber measures are considered alone.

[1] Italic figures in parentheses refer to Literature Cited, p. 53.

In an effort to determine the true correlation between each of the 15 pairs of factors representing the 6 fiber measures, that is, the relationships after eliminating the effect of all other associated fiber properties, Webb and Richardson reported in the same publication (*31*) a corresponding series of values for the partial correlation coefficients, as based on the same body of data that was used in the previous simple correlation analyses. At the time of their 1945 publication, it was thought that those partial correlation values possessed distinct advantages and reflected certain meaningful information. However, in the light of new information presented in this report concerning some limitations and uncertainties established for partial correlation coefficients, as a result of associated cotton fiber-measure interrelationships, it is not believed now that those partial correlation values constituted as pure a measure for the true or net relationship between any two factors in such a complex system as formerly was thought. Moreover, on the basis of the evidence presented in the present paper, as obtained from special coupling and weighting processes of the fiber-measure interrelationship data, it is now thought that simple correlation values reflect more meaning than formerly was considered possible.

About 1940, the Hertel Fibrograph, which is an optical instrument for evaluating upper half mean length, mean length, and length uniformity ratio of cotton fiber samples, and the Pressley tester for evaluating cotton fiber strength on the basis of flat-unwrapped bundles became available. Both of those instruments were adopted immediately and widely for general use in various cotton fiber research and testing laboratories across this country primarily because of the greater speed and lower cost per test which they afforded over the alternative sorter fiber length array method and the Chandler round-wrapped bundle fiber strength test. Those testing instruments represent the beginning of a wave of new, improved, and more rapid test methods for cotton fiber laboratories, a movement which has continued through the years, widening its scope and accelerating its speed with the passing of time.

Substituting the new fiber length and strength measures in place of the sorter length and Chandler strength measures, Webb and Richardson (*32*) made simple and partial correlation analyses for the 15 pairs of fiber measures representing the regional variety series of cottons, crop years 1935–37, as before. The raw-cotton quality factors used in those analyses were: Fibrograph upper half mean length, length uniformity ratio, fiber weight per inch, Pressley unwrapped flat-bundle strength (0 gauge), percentage of mature fibers, and grade number (classification). The findings that were obtained are tabulated below, the paired factors being listed in order of descending values for the respective coefficients of simple correlation:

Rank	*Fiber measures correlated*	*Coefficients of correlation (r)*[1]
(1)	Uniformity ratio with fiber weight per inch	+0.664
(2)	Fiber weight per inch with percent of mature fibers	+.611
(3)	Upper half mean length with fiber weight per inch	−.474
(4)	Fiber weight per inch with (P) fiber strength	−.471
(5)	Uniformity ratio with percent of mature fibers	+.470
(6)	Grade with uniformity ratio	−.384
(7)	Grade with upper half mean length	−.366
(8)	Upper half mean length with uniformity ratio	−.328
(9)	Grade with percent of mature fibers	−.321
(10)	Percent of mature fibers with (P) fiber strength	−.281
(11)	Uniformity ratio with (P) fiber strength	−.239
(12)	Grade with fiber weight per inch	−.225
(13)	Upper half mean length with (P) fiber strength	+.117*
(14)	Upper half mean length with percent of mature fibers	+.065*
(15)	Grade with (P) fiber strength	+.003*

[1] The sign indicates the direction of the relationship between the respective pairs of factors.
*Statistically insignificant, being less than 3 times its standard error.

No suggestion of a curvilinear relationship was observed with any of the 15 pairs of fiber measures when the data for each pair were plotted in scatter diagrams. Although the graphic charts revealed a relatively wide scatter for the data representing each pair of fiber measures, they indicated a linear trend in every instance, as based on the wide ranges of data involved and representing the 16 combined varieties of American upland cottons included.

No further studies were made of the fiber-measure interrelationships by Webb and Richardson until those which are reported by Webb in the present paper. Such omission was due to the fact that, for the next 15 years, the principal objectives of the many relationship studies which they con-

ducted were focused primarily on the development of numerous regression equations whereby yarn strength, yarn appearance, and the like could be estimated or predicted on the basis of data representing various numbers and combinations of fiber measures. For that purpose, the main criterion of acceptance or rejection of an equation is its standard error of estimate; that is, the smaller the standard error of estimate in terms of a dependent variable, or the higher the degree in precision of prediction of such, the more reliable and better is the regression equation for its intended purposes.

Thus, for estimating or predicting purposes, it is of no particular consequence to know the degree of and the effect from the various individual and combined fiber-measure interrelationships which are present and which are operating in the multiple correlation analysis. More particularly, for these estimating or predicting purposes, it is immaterial whether the individual and total fiber measures are contributing their effects on the dependent variable in a relatively pure or specific manner, or whether they do so in more or less disguise and subterfuge under the influence of accumulated net effects arising from some other interrelated fiber properties or measures. However, as shown by the new results reported in the present paper, the larger the net amount of positive effects on 22s yarn strength which arise from the fiber-measure interrelationships representing five fiber measures, including the alternative fiber strength measures of ⅛-inch and 0 gauge lengths, the larger is the total amount of variance explained in such yarn strength by those five factors; generally the smaller is the standard error of yarn-strength estimate associated with the regression equation; and generally the greater is the degree in precision of yarn-strength estimate or prediction possessed by the regression equation.

Interactions and Residuals With Strength of 22s Yarn, Crop Years 1941–44

In 1949, Webb, Richardson, and Popka (*33*) reported results from multiple and simple correlation analyses dealing with the relation of six elements of raw-cotton quality to the skein strength of 22s yarn (regular and formerly conventional draft) by crop year, variety, and staple length. This study was based on 824 American upland cottons included in the annual variety series for the 4 crop years of 1941–44. Following are the fiber measures that were included in those analyses: Upper half mean length, length uniformity ratio, fiber fineness (weight per inch), Pressley fiber strength (0 gauge), percentage of mature fibers, and grade index. Beta coefficients were used exclusively, for the first time in this series of published reports, as a measure of the relative net effect of the respective cotton-quality factors on yarn strength. Thus, by making supplemental calculations in connection with certain of those published findings, it is now possible to derive some values of interest as a basis of comparison with the total interactions and residuals reported in the present paper for three series of cottons representing short staple, medium staple, and long staple levels.

For the 824 cottons, crop years 1941–44, the multiple correlation analysis using the six foregoing measures of cotton quality (including fiber strength at the 0 gauge) with skein strength of 22s yarn (regular draft) gave results, as follows:

	Percent
(1) Coefficient of multiple determination ($\bar{R}^2 \times 100$)	70.56
(2) Sum of 6 individual betas$^2 \times 100$	60.81
Interactions and residuals (1)−(2)	+9.75

For the 514 short staple, medium staple, and long staple American upland cottons, crop years 1954–57, the multiple correlation analysis using the five measures of cotton quality listed in the present paper (including fiber strength at the 0 gauge) with skein strength of 22s yarn (long draft) furnished unpublished results, as follows:

	Percent
(1) Coefficient of multiple determination ($\bar{R}^2 \times 100$)	75.39
(2) Sum of 5 individual betas$^2 \times 100$	55.86
Interactions and residuals (1)−(2)	+19.53

The two sets of values, as shown in the foregoing tabulations, are in remarkably close agreement considering the fact that the crop years were 13 years apart; that the growth conditions were different; that the varieties differed somewhat; that regular draft 22s yarn was used in the 1941–44 study, whereas it was long draft 22s yarn in the 1954–57 study; that six quality factors were included in the earlier study whereas five factors were used in the later study; and that fiber weight per inch and percentage of mature fibers were included in the first analysis whereas micronaire values (fiber fineness in combination with maturity) were substituted for those values in the second analysis.

In the 1941–44 study, the multiple correlation analyses made with the data stratified by individual staple lengths showed a pattern of values for total interactions and residuals ($\bar{R}^2 \times 100 -$ sum of 6 betas$^2 \times 100$) similar to that reported in this paper for cottons of different staple length levels, when fiber strength at the 0 gauge was included in the analyses. That is, with the staple-length groupings of ⅞ inch, 29/32 inch, 15/16 inch, 31/32 inch, and 1 inch, the individual values for interactions and residuals ranged from −6.87 percent to −30.79 percent; and, with the staple length groupings of 1 1/32 inches, 1 1/16 inches, and 1 3/32 inches, the individual values for interactions and residuals extended from +2.43 percent to +15.81 percent.

Interactions and Residuals With Strength of 22s Yarn, Crop Years 1945–47

In 1950, Webb and Richardson (*34*) reported results from multiple and simple correlation analyses concerning the relation of six factors of raw-cotton quality to the skein strength of 22s and 50s yarn (long draft) by crop year, variety, and staple length. This study included 828 American upland cottons from the test series for selected cotton improvement groups and the experiment station annual variety series, crop years 1945–47. Fiber measures used were as follows: Upper half mean length, length uniformity ratio, fiber fineness (weight per inch), Pressley fiber strength (0 gauge), percentage of mature fibers, and grade index.

For the 828 cottons, crop years 1945–47, the multiple correlation analysis using the six foregoing measures of cotton quality (including fiber strength at the 0 gauge) with strength of 22s yarn (long draft) furnished the following results:

	Percent
(1) Coefficient of multiple determination ($R^2 \times 100$)	82.08
(2) Sum of 6 individual $\text{betas}^2 \times 100$	64.01
Interactions and residuals (1) − (2)	+18.07

The value of +18.07 percent for the total interactions and residuals, as shown above for the group of 828 cottons from the 1945–47 crops with strength of 22s long draft yarn, is almost identical with the value of +19.53 percent previously referred to for the interactions and residuals identified with the group of 514 cottons from the 1954–57 crops with strength of 22s long draft yarn.

The values for interactions and residuals connected with the 1945–47 cottons, by individual staple-length groupings of ⅞ inch, 29/32 inch, 15/16 inch, 31/32 inch, 1 inch, and 1 1/32 inches, ranged from −1.05 percent to −63.76 percent; and, by individual staple-length groupings of 1 1/16 inches, and 1 3/32 inches, the values extended from +5.82 percent to +6.70 percent.

Thus, the values obtained with the 1945–47 cottons followed, in general, the pattern of corresponding findings reported earlier for the 1941–44 cottons. Some variation in values occurred, however, as naturally might be expected, especially when the respective ranges of data were so severely restricted as in the 1/32-inch stratification by staple length. It is particularly noteworthy that, when using the same six fiber measures in the correlation analyses, similar trends in values for total interactions and residuals were obtained with skein strength of 22s yarn, even though the yarns of 1941–44 cottons were processed by regular draft whereas those of the 1945–47 cottons were processed by long draft.

Fiber Strength at ⅛-Inch Gauge

About 1950, the fiber bundle strength test at the ⅛-inch gauge spacing came into existence and it was successfully applied in various cotton fiber laboratories. Interest in this new fiber strength test developed immediately and at a rapid rate, as it was soon learned that the measure of fiber strength at the ⅛-inch gauge generally gave an appreciably higher degree of correlation with cotton yarn strength and was a more important factor toward cotton yarn strength than the alternative measure of fiber strength at the 0 gauge, which had been used generally up until that time. Both fiber strength tests, ⅛-inch gauge and 0 gauge, are currently made in many cotton fiber research and testing laboratories and, today, they are used about equally in this country, if not around the world.

Thus, two radically different kinds of data on fiber bundle strength are now currently available for cotton on a large scale and, as the data accumulate and the observations sharpen, increasing confusion and uncertainty are arising as to the precise meaning, significance, and comparability of the data for the ⅛-inch gauge and 0 gauge tests. In spite of many special and comparative studies that have been made to date by investigators in this country and abroad, nobody yet knows the answers to those questions. Speculation, therefore, exists today among cotton-fiber and textile technologists concerning the true meaning and comparability of fiber strength as such for cottons representing wide ranges of fiber length, fineness, and strength, as evaluated by those two test methods. Further consideration will be given to these matters in the "Discussion" chapter of this report.

Values for fiber strength at the ⅛-inch gauge were first included in the annual cotton quality survey, published by the Cotton Division of the Agricultural Marketing Service for the crop of 1954. Corresponding data for fiber strength at the 0 guage, however, were not published in the summary report for that year. But, beginning with the crop year of 1955 and continuing for successive crop years, values for fiber strength at both the ⅛-inch gauge and 0 gauge have been published annually and periodically throughout each harvesting season.

Interactions and Residuals with Strength of 22s Yarn, by Crop Year, 1955–60

Nickerson and others (*9*) recently reported results obtained from a large number of multiple and simple correlation analyses, representing selected American upland cottons by individual crop years from 1946 to 1960, and involving varying numbers and combinations of selected measures of quality in reference to fiber, processing,

and yarn properties. The findings reported by those authors for strength of 22s yarn correlated with five factors of raw-cotton quality, including fiber strength at the ⅛-inch gauge versus fiber strength at the 0 gauge, are of particular interest to the major pattern of results obtained from the present study and covered in this report. The other four cotton quality factors common to Nickerson's alternative sets of correlation analyses were as follows: Grade index, staple length, micronaire, and uniformity ratio.

On a basis of the values published by Nickerson and her associates for the coefficients of multiple correlation ($\overline{R}$) and for the respective five beta coefficients identified with each multiple correlation analysis, supplementary calculations have been made to determine values for the following: Coefficients of multiple determination ($\overline{R}^2 \times 100$), sum of the 5 individual betas$^2 \times 100$, and the total interactions and residuals ($\overline{R}^2 \times 100$—sum of 5 individual betas$^2 \times 100$). The values so derived from the published report by Nickerson and others, representing the six individual crop years of 1955–60 for American upland cottons of different staple length levels, are of considerable interest to the present study and report.

In the light of the findings derived from the publication by Nickerson and others, it is evident that the values for $\overline{R}^2 \times 100$, for the sum of 5 betas$^2 \times 100$, and for total interactions and residuals for each group of five factors with each staple-length level of cottons (short staple, medium staple, and long staple) varied considerably for the different crop years involved. This is not surprising; in fact, it is to be expected due to the appreciable annual variation in distribution, ranges, and levels of data that went into the respective correlation analyses and, also, to the relatively small and variable numbers of samples represented in the various annual series for the short staple and for the long staple cottons.

The values calculated from the Nickerson data for the annual total interactions and residuals followed a pattern more or less similar, when the alternative groups of fiber measures were correlated with 22s yarn strength, to that furnished by the short staple, medium staple, and long staple series of cottons representing the 4 crop years of 1954–57 on which the present study and report are based. More particularly, as derived from the data published by Nickerson and associates, for the five fiber measures including fiber strength at the ⅛-inch gauge with 22s yarn strength, the mean total interactions and residuals were −3.36 percent for the short staple, +17.69 percent for the medium staple, and +37.87 percent for the long staple cottons. For the five fiber measures including fiber strength at the 0 gauge, the corresponding mean values for total interactions and residuals shown by the cottons of increasing staple length levels were as follows: −54.56, +11.63, +37.86 percent.

The mean total interactions and residuals identified with the five fiber measures, including fiber strength at the 0 gauge, for the four annual series of short staple cottons used by Nickerson and associates is particularly noteworthy (−54.56 percent) and the four individual serial values that entered into the mean value are equally noteworthy (−68.28, −48.83, −66.36, −34.78 percent). The value presented in the present report for total interactions and residuals is −19.79 percent for the 81 short staple cottons, represent- the 4 crop years of 1954–57, when five fiber measures—including fiber strength at the 0 gauge—were correlated with 22s yarn strength. A value of −38.62 percent, however, was obtained by use of the same set of factors with 59 short staple cottons selected out of the foregoing 81 short cottons to represent a more restricted range of cottons than the former.

On the basis of the comparative results listed in the foregoing, it is felt that the findings reported in the present paper for total interactions and residuals, representing cottons from the 4 crop years of 1954–57, are on the conservative side. The larger and more variable values reported herein on a per annum basis, as derived from annual data published by Nickerson and associates, indicate (1) the nature and degree of the possible factorial relationships and interrelationships which are present in cotton quality and which differ more or less from crop year to crop year (as well as from location to location and from variety to variety), (2) why the fiber and processing qualities of individual cottons and of blends or mixes of cottons, as evaluated in research and testing laboratories and in commercial spinning plants of the textile industry, fluctuate so appreciably from season to season, and (3) why analytical results should be based on samples representing at least 3 to 5 crop years, wide geographical and quality ranges, and relatively large numbers to give the comparatively stable values needed for serving empirical purposes connected with the evaluation and utilization of cotton quality.

Interactions and Residuals With Strength of Various Yarn Sizes

Thus far, all values presented for total interactions and residuals have been in terms of explainable variance with respect to skein strength of 22s carded yarn. The question arises as to whether similar or dissimilar values should be expected for total interactions and residuals identified with strength of other sizes of yarn over an extended range, giving due regard to the staple length of the raw cottons used and to the practical range of yarn sizes spinnable from the cottons.

Available comparative values are limited in number, but several will be cited for purposes of illustration.

As based on data reported by Webb and Richardson (*34*) for a total of 828 American upland cottons, crop years 1945–47, it is now calculated that the six fiber measures (including fiber strength at the 0 gauge) gave values for total interactions and residuals with yarn strength as follows: + 18.07 percent with 22s yarn and +23.00 percent with 50s yarn.

Based on data reported by Webb (*30*) for three series of American upland cottons, representing each of 3 later crop years, it is now calculated that the six fiber measures (including fiber strength at the 0 gauge) furnished the following values for total interactions and residuals with yarn strength:

		Interactions and residuals with yarn strength of—		
Year	*Cottons*	*22s*	*36s*	*50s*
1948	277	−4.50	+0.29	+4.20
1949	260	+33.50	+35.03	+33.29
1950	305	+21.42	+22.42	+19.35
Mean	---	+16.81	+19.25	+18.95

Thus, in the light of these results, it appears that the total of the interactions and residuals for a combination of fiber measures, representing a large series and wide range of cottons, is more or less the same whether strength of 22s or 50s yarn is used as the dependent variable in the multiple correlation analysis.

Fiber Strength ⅛-Inch Gauge Versus Fiber Strength 0 Gauge

Many comparative tests of various kinds have been made by workers at different institutions during the past 10 years in reference to the fiber strength measures identified with the ⅛-inch gauge and with the 0 gauge. Only those findings and publications, however, are included in this limited review which have a more special meaning in reference to values furnished by the Pressley fiber strength tester, when operated at the ⅛-inch gauge and at the 0 gauge, as influenced by other cotton fiber properties.

The University of Texas through its Cotton Economic Research Department published a preliminary report (*29*) in 1955 entitled "Pressley Strength Tester Results at Zero Compared with One-Eighth Inch Gauge Lengths," and Wolf, a former member of that organization, published a similar report (*35*) in 1959 entitled "Comparison of the Results Obtained at Zero Test Length and a Test Length of ⅛-In. with the Pressley Fiber Bundle Strength Tester." Those two publications appear to be based substantially, if not entirely, on the same data. Using a limited number of cottons in most phases of the study but representing ranges of upper half mean length and fiber fineness, both publications state in effect the following: The results reported indicate that, at the ⅛-inch test length, fiber strength is not measured directly and that, on correlating the fiber strength values at this test length with yarn strength, a certain indirect relationship is obtained between yarn strength and a complex of fiber properties, such as fiber length and fiber strength.

Lunenschloss and Hummel, research workers at the German Textile Industries Research Institute, Reutlingen, recently have made extensive studies with the alternative fiber strength tests when applied to a large number and wide range of cottons. Those authors published in 1961 a report (*8*) entitled "The Dependence of the Ratio Between Bundle Strengths at Gauge Lengths of 0 and ⅛″ Upon Fiber Length and the Breed of Cotton." The authors' English abstract of their article is quoted herewith, as follows: "After comparative experimentation to ascertain the firmness of the bundle of various types of cotton, using a setting length of 0 and ⅛″, the authors arrive at a higher ratio of firmness at ⅛″ to 0 with long-staple Egyptain cottons and American cottons of Egyptian breed. That means that the degree of firmness at ⅛″ setting length shows less decline, by reason of less frequent or less pronounced weak points, than is the case with short-staple cotton. It remains to be clarified whether this property is a natural one or a result of differing methods of ginning and their attendant different types of treatment. So far as practice is concerned, it may be assumed possible to establish, on the basis of this proportion of firmness, the presence of long-staple, high-quality cottons even when treatment has so destroyed the staple that it is no longer sufficient for purposes of identification."

The work and findings of Lunenschloss and Hummel will be considered further in the "Discussion" chapter, as well as pertinent results reported by several other investigators.

SAMPLES, TESTS, AND DATA

All fiber, processing, and product-quality tests for the cottons used in this study were made by the Cotton Division, Agricultural Marketing Service, in its laboratories at Clemson, S.C., and at College Station, Tex. The basic data used in these correlation analyses were obtained from the annual summary of test results (*23*), (*24*), (*26*), and (*27*) published by the Cotton Division for the four crop years 1954–57, except as follows:

(1) Values for fiber strength at the 0 gauge spacing, crop year of 1954, were published by the Cotton Division only in its monthly reports (*16* through *21*) and they are complete but for 6 late-season samples.

(2) Micronaire values for the crop years of 1954 and 1955 were calculated from Causticaire laboratory data sheets, as they were not published by the Cotton Division in either its summary or monthly reports for those 2 crop years, Causticaire fineness and maturity values having been published instead.

Cottons

All cottons represented in the multiple and simple correlation analyses reported herein were of the American upland type, *Gossypium hirsutum*, and they were grown commercially in selected cotton improvement groups across the Cotton Belt of the United States, within their general area of growth adaptation, during the 4 crop years of 1954–1957. The cottons were ginned on commercial saw gins serving the respective cotton improvement groups. Almost every variety and location of growth was represented by early season, midseason, and late-season samples.

In supplemental studies concerning ratio values for fiber strength ⅛-inch/0, data representing the foregoing upland cottons were used. In addition, data representing samples of the American Egyptian type of cotton, *Gossypium barbadensae,* crop years 1954–1957, were included for comparison. The basic data for the American Egyptian cottons were also published by the Cotton Division in its supplemental reports (*16* through *21*) and in its annual summary of test results (*23*, *24*, *26*, *27*). Those cottons were grown under conditions of irrigation adapted to cotton production in Arizona, New Mexico, and Texas, and they were ginned on commercial roller gins within their respective areas of growth.

In further supplemental studies dealing with ratio values for fiber strength ⅛-inch/0, as applied to current cottons, data representing samples of American upland and American Egyptian cotton grown during the crop year of 1961 were used. Those data were published by the Cotton Division in its summary of test results (*28*) for cottons commercially grown and ginned in their respective areas by the procedure previously described for earlier crop years. For the crop year of 1961, however, collection of the test samples was made at intervals of every 3 weeks throughout the harvesting season instead of early-season, midseason, and late-season periods, as formerly was done.

Sampling

Classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton improvement area for each period of harvesting, until 8 to 10 pounds of raw cotton had been accumulated.

The original grade and staple length designations, which served as the basis for selecting and compositing the comparable lots of cotton for test purposes, were those assigned to the individual samples of raw cotton by cotton specialists of the U.S. Department of Agriculture. Classification of the samples was made in accordance with official standards for staple length and grade, as described for American cotton in the publication entitled "The Classification of Cotton" (*25*).

As a result of the method used for selecting the samples, obviously not every grade and staple length in the range appearing in each cotton improvement area was represented by the test cottons. But, for each growth area involved and for the U.S. Cotton Belt as a whole, the test samples are viewed as constituting a substantial and extensive coverage of the major varieties and qualities embraced by the annual crops of American cotton under consideration.

Textile Processing

Details of the processing procedure by which the cottons were converted into yarns may be found in the reports (*23*, *24*, *26*, *27*) setting forth the fiber and spinning test results for the 4 crop years involved. The report (*22*) that describes the cotton testing services of the Cotton Division includes not only processing procedures but fiber, yarn, and other tests as well.

All upland cottons used in this study were processed through the picker and card by the same standard procedure. On the basis of past performance, the varieties were grouped according to the staple length expected in their specified areas of growth. In general, the rates of carding were as follows:

(1) Short staple cottons, $1\frac{5}{16}$ inch and shorter in staple length, 12½ pounds per hour;

(2) Medium staple cottons, from $^{31}/_{32}$ inch through $1\frac{1}{16}$ inches in staple length, $9\frac{1}{2}$ pounds per hour;

(3) Long staple cottons, from $1\frac{3}{32}$ inches through $1\frac{1}{4}$ inches, $6\frac{1}{2}$ pounds per hour.

Yarns were obtained from all cottons by processing them on long-draft spinning equipment and they possessed a semihard twist. The twist multiplier varied with the upper half mean length of the cottons, the one selected for each cotton being that which gave approximately the maximum yarn strength for an average or typical cotton of the particular classified staple length. The twist multiplier used in each case, therefore, was not selected to compensate for the influence of other fiber properties involved but represented an empirical selection.

Fiber Properties

Five factors of raw-cotton quality, including alternative measures of fiber strength (⅛-inch gauge and 0 gauge), were used as variables in the correlation analyses of this study, as follows:

Upper half mean length, in inches, as determined by the fibrograph method

Length uniformity ratio, index, as determined by the fibrograph method

Fiber fineness and maturity in combination, as evaluated for untreated samples by the micronaire method and expressed in micronaire scale units

Fiber strength, expressed in terms of an index, as determined by the Pressley tester with ⅛-inch gauge spacing between the gripping jaws

Fiber strength, in terms of 1,000 pounds per square inch (p.s.i.), as determined by the Pressley tester with a zero (0) gauge spacing

Grade of cotton, expressed as an index. (Grade is an important factor of raw-cotton quality for purposes of marketing, textile processing and product quality, as described in The Classification of Cotton (*25*), but grade is not a fiber property in the generally accepted sense.)

The fiber tests and methods which provided the data for these correlation analyses are those described in the annual summary of test results (*23*), (*24*), (*26*), (*27*); in Cotton Testing Service (*22*); and in ASTM Standards on Textile Materials (*1*).

The conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned by cotton specialists, is shown on page 80 of the 1961 summary of test results (*28*).

In calculating the test results for fiber strength at the ⅛-inch gauge, the Pressley ratio is obtained by dividing the weight of the test specimen in milligrams into the strength of the specimen in pounds, and then adjusting the quotient to a standard level on the basis of results obtained from check-test cottons. This ratio for an individual cotton, when divided by an average ratio of 3.19 and multiplied by 100, is converted to a fiber-strength index which indicates higher-than-average fiber strength by index values larger than 100 and lower-than-average strength by values smaller than 100.

A Pressley strength index of 100 equals average fiber strength for the 1954 crop of commercial American upland cottons tested, representing a beam-reading-to-weight-specimen ratio of 3.19 for the ⅛-inch gauge spacing, and corresponding to a fiber strength of 84,000 p.s.i. for the 0 gauge spacing.

In calculating the test results for fiber strength at the 0 gauge spacing, the Pressley ratio is obtained as described for the ⅛-inch gauge spacing. The formula for converting the Pressley strength-weight ratio values at the 0 gauge spacing into terms of 1,000 p.s.i. is as follows:

$$X_{33}=10.8116\ X_{22}-0.12$$

Where X_{33}=Estimated fiber strength, in 1,000 p.s.i.

X_{22}=Pressley strength-weight ratio at 0 gauge

Yarn Size

Only one size of carded yarn has been represented in the correlation analyses reported herein; namely, 22s as expressed in terms of the long established English yarn numbering system. One size of yarn was used throughout this study in order to accommodate all cottons, from the shortest to the longest in staple length, on the same common level of yarn size.

Yarn Strength

Only skein strength of 22s carded yarn has been used as the dependent variable in the various correlation analyses of this study. Conventional skein tests of all yarns were made according to the generally adopted procedure described in ASTM Standards (*1*) and referred to in cotton testing service (*22*), as well as in the annual summary of test results (*23, 24, 26, 27*).

Atmospheric Conditions for Fiber and Yarn Testing

All fiber and yarn strength tests made on the samples included in this study were performed under controlled atmospheric conditions possessing a temperature of 70° F. ±2° and a relative humidity of 65 percent ±2 percent, as specified by ASTM Standards on Textile Materials (*1*).

CORRELATION ANALYSES AND MEASURES

This report covers results obtained from a systematic and extensive series of multiple and simple correlation analyses made with data representing each of three groups of American upland cottons conforming to three general staple-length levels; namely, short staple, medium staple, and long staple. A complete set of multiple and simple correlation analyses was made with each series of cottons. The comparative values so obtained have been coupled together in various ways in an effort to reveal how the intricate, obscure, and entangled interrelationships between the fiber measures affect the conventional evaluations of cotton quality and, insofar as possible, to evaluate their contributing effects in terms of explainable variance in skein strength of 22s carded yarn.

The stated objective is difficult to attain because of the size and complexity of the problem; because of limitations in analytical techniques available today; and because of a lack of precise meaning at the present time for various measures identified with cotton fiber properties and correlation analysis. In addition, the problem is never static but is changing all the time, as a result of known and unknown modifications continuously being made in the existing combinations of cotton fiber properties through breeding and improvement; of new, improved, and more complete cotton fiber tests being currently developed and applied; and of new and more efficient textile processing machines and methods being currently developed and used for converting cotton fibers into yarns.

But information on cotton quality interrelationships is needed for the advancement of cotton fiber technology and for making some long overdue breakthroughs. Moreover, such information is needed for the benefit of cotton breeding and fiber improvement as well as of processing and product quality. Obviously, therefore, all such information constitutes important considerations of interest and value to the commercial production, marketing, and utilization of American cotton, and to strengthening the competitive position of cotton in world markets against the rapidly rising synthetic fibers.

Multiple Relationships and Measures

Two multiple linear correlation analyses were made by conventional methods, using the data representing each of the three series of cottons, making a total of six such analyses in all. For each series of cottons, skein strength of 22s carded yarn was correlated with five factors of raw-cotton quality, as follows: Upper half mean length, length uniformity ratio, micronaire (representing fiber fitness and maturity in combination), grade index, and fiber strength at the ⅛-inch gauge spacing. A parallel multiple analysis was made for each series of cottons, using the first four factors but substituting fiber strength at the zero (0) gauge spacing for fiber strength at the ⅛-inch gauge.

The overall relationships embraced by the data included in each multiple analysis were evaluated by the conventional measures of: Coefficient of correlation ($\bar{R}$) for denoting the degree of association existing between the dependent and independent variables involved; coefficient of determination ($\bar{R}^2 \times 100$) for revealing the percentage of variance in strength of 22s yarn explainable by each combination of five fiber measures; absolute standard error of estimate ($\bar{S}$) for indicating the precision of yarn-strength prediction in terms of pounds, as based on each group of five fiber measures; and relative standard error of estimate ($\bar{S}$) for showing the relative precision of such yarn-strength predictions on a percentage basis.

Net Effects

The relative net effect or importance of each fiber measure toward strength of 22s yarn, as identified with each multiple analysis, was evaluated by the two measures commonly used; namely, beta coefficients and coefficients of partial correlation. Those two measures are used by cotton technologists more or less indiscriminately and with about equal confidence. While those alternative statistical measures do generally give similar rankings for the importance of respective cotton fiber mesaures toward yarn strength, some instances of disparity between the two sets of values have been observed in this study. By definition and mathematical calculation, the two measures are somewhat different and the inconsistencies noted herein appear to be explainable, in substantial part, on the basis of those differential features.

Interactions and Residuals

The value for total interactions and residuals is expressed in terms of explainable yarn-strength variance and it includes the net sum of positive and negative effects arising from all possible pairs (10) of fiber measures involved in each multiple analysis and of all other interacting and residual effects that may be present as well. It requires only a simple calculation, however, to derive the value for the complex of total interactions and residuals represented in a multiple analysis, as indicated by the following: Coefficient of multiple determination ($\bar{R}^2 \times 100$) minus the sum of the 5 individual betas$^2 \times 100$, with the appropriate sign being given to the difference so obtained, as the combined effects of all the interactions and residuals involved in a multiple analysis may result in an overall positive or negative quantity.

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Gross Effects

The relative gross effect or importance of the six respective fiber measures toward strength of 22s yarn, as identified with each of the three series of cottons, was established by simple correlation analysis. Values are shown for the respective coefficients of simple correlation ($\bar{r}$) and coefficients of simple determination ($\bar{r}^2 \times 100$). Ordinarily, when standing alone, values obtained from simple correlation analysis possess relatively little significance and only minor interest, as they refer merely to gross relations and gross effects, a condition which arises because of the fact that simple correlation analysis ignores all other factorial relationships and interrelationships involved. But in a study of this kind, where effort is being made to unmask and evaluate the effects of the fiber interrelationships bound up in data representing cottons stratified by staple-length level, values from such simple correlation analyses can be revealing and helpful, if they are viewed and interpreted in the light of values obtained for corresponding beta coefficients derived from multiple correlation analysis of the data for the same series of cottons. In the latter case, all or practically all of the associated effects of the factorial interrelationships are taken into consideration and removed from the respective beta coefficients, thus making them the best measures known today for revealing the relative net effect or importance of a particular cotton fiber measure toward any measure of yarn and fabric quality.

Pairs of Fiber Measures

The relationship occurring between all possible pairs of the fiber measures used in this study, as identified with each of the three series of cottons, was determined by the conventional method of simple correlation analysis as currently used.

Corrected Values

All values obtained from the multiple and simple correlation analyses reported herein represent corrected values; that is, conventional adjustments were made in the preliminary values obtained to accommodate for varying numbers of observations having been represented in the respective correlation analyses. For the short staple series of cottons, the number of cottons was 81; for the medium staple series, 260; and for the long staple series, 173.

DISTRIBUTION OF STAPLE LENGTHS, VARIETIES, AND DATA REPRESENTED IN ANALYSES

In considering the correlation values, interpretations, and conclusions which follow, it is important first of all to examine the distribution of the cottons by staple length and variety represented in the respective analyses, and the distribution of the fiber and yarn-strength data which served as the basis of the individual analyses. Those features influence appreciably the results and meaning of results from correlation analyses, and no valid interpretations and conclusions can be made with respect to such findings without careful consideration of their background nature.

Staple Length

The distribution of cottons, by staple length, for the three series of cottons representing different staple length levels is shown in table 1.[2] It will be noted that the staple length of the short staple series of cottons extended from $\frac{13}{16}$ inch to $1\frac{1}{32}$ inches; that for the medium staple series of cottons, from $\frac{7}{8}$ inch to $1\frac{1}{8}$ inches; and that for the long staple series of cottons, from 1 inch to $1\frac{1}{4}$ inches. The ranges in staple length, therefore, were appreciable and approximately equal, being $\frac{7}{32}$ inch for the short series, $\frac{1}{4}$ inch for the medium series, and $\frac{1}{4}$ inch for the long series.

The staple-length distributions are reflected in the central tendency possessed by each series of cottons; the mean staple length was $\frac{15}{16}$ inch, for the short cottons, $1\frac{1}{32}$ inches for the medium, and $1\frac{3}{32}+$ inches for the long cottons. Thus, appreciable and approximately equal steps in mean staple length occurred between the successive series of cottons: $\frac{3}{32}$ inch between the medium and short series of cottons and $\frac{1}{16}+$ inch between the long and medium series of cottons, making a total length-level difference of $\frac{5}{32}+$ inch between the two extreme groups of cotton.

For further consideration of these details, see the section entitled "Distribution of Basic Data Used in Correlation Analyses" which appears in the "Discussion" chapter.

Varieties, Growth Areas, and Seasons

The distribution of samples, by variety, State, and crop year is shown for the short staple series of

[2] All tables are grouped in the appendix of this report; hereafter they will be referred to by table number only.

cottons in table 2, for the medium staple series in table 3, and for the long staple series in table 4. The short staple series of cottons is represented by 12 varieties grown in Texas and Oklahoma, crop years 1954–57. The medium staple series is represented by 12 varieties grown in 13 States across the Cotton Belt in 1954. The long staple series is represented by 10 varieties grown in 8 states, crop years of 1954–56. Accordingly, the cottons analyzed in this study represent substantial coverage of commercial varieties and growth areas for the 4 crop years involved.

Basic Data

Values for the mean, standard deviation, and coefficient of variation representing the data for all the factors of raw-cotton quality used in the correlation analyses with skein strength of 22s carded yarn, as identified with the three series of cottons representing different staple-length levels, are shown in table 5. Corresponding values for the maximum, minimum, and range of data for each factor with each series of cottons are listed in table 6. Careful study of this detailed information should be made when considering the correlation values, interpretations, and conclusions which follow.

EVALUATION OF MULTIPLE RELATIONSHIPS

The results obtained from multiple correlation analyses relating skein strength of 22s carded yarn to five cotton fiber measures, including the alternative measures of fiber strength and representing three series of American upland cottons selected to represent different staple-length levels, are summarized in table 7.

The coefficient of correlation ($\overline{R}$) for the five fiber measures, including fiber strength at the ⅛-inch gauge spacing, increased from 0.754 for the series of short staple cottons to 0.761 for the medium staple cottons to 0.906 for the long cottons. The coefficients of correlation for the five measures, including fiber strength at the 0 gauge spacing, were 0.470 for the short, 0.641 for the medium, and 0.915 for the long cottons.

More meaningful for the purposes of this study are the values for the coefficient of determination ($\overline{R}^2\times100$) shown in table 7, which indicate the percentages of variance in the strength of 22s yarn explained by the combined factors of cotton quality used in the respective analyses. The $\overline{R}^2$ value, by mathematics and definition, is a function of the combined relationships and interrelationships of all the factors represented in the correlation analysis.

In particular, the five fiber measures, including fiber strength at the ⅛-inch gauge, explained 56.83 percent of the yarn-strength variance for the short staple cottons, 57.91 percent for the medium staple cottons, and 82.02 percent for the long cottons. Thus, this combination of five fiber measures accounted for 25.19 percent units more yarn-strength variance with the long staple cottons than with the short staple cottons.

On the other hand, the five fiber measures, including fiber strength at the 0 gauge, explained *only* 22.14 percent of the yarn-strength variance for the short cottons, 41.12 percent for the medium staple cottons, but 83.63 percent for the long cottons. This combination of five fiber measures, therefore, explained 61.49 percent units more yarn-strength variance with the long staple cottons than with the short staple cottons, a difference approximately 2½ times that shown by the five fiber measures, including fiber strength at the ⅛-inch gauge. But, as the $\overline{R}^2$ values derived from the two analyses are approximately the same for the series of long cottons, this much larger difference is caused by the extremely small $\overline{R}^2$ value furnished by the five fiber measures with fiber strength at the 0 gauge for the short staple cottons.

Examining the differences between the parallel values for $\overline{R}^2\times100$, as shown in table 7, it will be seen that the five fiber measures, including fiber strength at the ⅛-inch gauge, explained 34.69 percent more variance in yarn strength with the short cottons than did the five fiber measures, including fiber strength at the 0 gauge; 16.79 percent more in the case of the medium staple cottons; and 1.61 percent less with the long cottons.

These comparative values and differences immediately raise the question of the cause or causes for them. Differences in the nature, degree, and scope of the interrelationships associates with the alternative fiber strength measures, as identified with cottons representing different staple-length levels, appear to be the primary cause. Much direct and indirect evidence to that effect has been developed in this study, some phases of which will be presented and discussed in the following pages of this report.

The absolute and relative standard errors of yarn-strength estimate shown in table 7 are self-explanatory and they follow in general line with the $\overline{R}$ and $\overline{R}^2$ values obtained from the respective correlation analyses, as influenced by the distri-

bution of data reported in tables 5 and 6 for the individual factors represented in each analysis. The variations in standard errors are revealing and possess interest, but as they do not contribute to the principal objectives of this study, no further consideration will be given to them in this report.

EVALUATION OF NET EFFECTS

The one and only mathematical expression for revealing the average relationships existing between a dependent variable and two or more independent variables, as evaluated by multiple correlation analysis, is the resulting regression equation. Every such estimating or predicting equation includes as many regression coefficients as there are independent variables represented in the analysis and also a constant factor for the equation as a whole. A plus or minus sign accompanies each regression coefficient, indicating the direction of the contribution of the independent variable to the dependent variable, and the constant value for determining the level of the final estimate or prediction may be either positive or negative.

In a mathematical sense, each regression coefficient in such an equation constitutes a measure of the average net effect of its representative independent variable toward the dependent variable; that is, the value shown for each regression coefficient indicates the average amount of net change in the dependent variable caused by a one-unit increase in its representative independent variable. But, the values for the series of regression coefficients throughout an equation are not comparable among themselves and, as such, they cannot be used as comparative measures of the relative net importance of the respective independent variables toward the dependent variable. This is because, for cotton fiber measures at least, the respective regression coefficients represent different units of measure, reflect different degrees of standard deviation, and occupy different levels of expression.

To eliminate the objections cited above, the regression coefficients identified with a particular equation or multiple correlation analysis can be made comparable by converting them to a common basis in terms of standard deviation. The value of the regression coefficient so converted becomes what is known as the beta coefficient. By mathematics and definition, the beta coefficient is a measure of the average amount of net change in the standard deviation of the dependent variable caused by a one-unit increase in the standard deviation of a particular independent variable.

In the light of the foregoing, the beta coefficient may be viewed mathematically as being to multiple correlation analysis what the coefficient of correlation ($\overline{r}$) is to simple correlation analysis, as both represent the ratio between the standard deviations identified with the independent and dependent variables involved. There is, however, a vast difference in meaning between those two correlation measures. The beta coefficient refers specifically to the relative net effect or importance of the independent variable toward the dependent variable, after the effects of the other associated factorial relationships and interrelationships have been removed. The coefficient of simple correlation ($\overline{r}$), on the other hand, refers loosely to the gross effect or importance of the independent variable toward the dependent variable; it includes the influences of all other associated factorial relationships and interrelationships and involves the net summation of a mass of cumulative and compensative effects.

A summary of the beta coefficients showing the net importance of each of the five fiber measures, including fiber strength at the ⅛-inch gauge, toward skein strength of 22s carded yarn, for each of the series of cottons, is shown in table 8; table 9 gives the parallel set of analyses when fiber strength at the 0 gauge was measured. The fiber measures are ranked in importance to yarn strength in those tables in order of descending beta values. Corresponding values for the square of the beta values also are shown in those tables, together with a summation of the beta and of the beta squared values for each series of cottons.

The results presented in tables 8 and 9 are useful for certain purposes, but they are more meaningful to the objectives of this study when tabulated and compared in another manner.

In table 10, a comparison is shown of the relative net importance of each of the five fiber measures toward skein strength of 22s carded yarn, as evaluated by beta coefficients obtained from analyses including alternative fiber strength measures, for each of the three series of cottons of different staple-length levels. For this purpose, values of the beta coefficients squared and multiplied by 100 have been used in order to translate the net contribution of each fiber measure from a relative and more or less abstract quantity into terms of yarn-strength variance; that is, the percentage of net yarn-strength variance explained by each fiber measure. The number shown in parentheses before each beta^2 value listed in table 10 indicates the rank of importance of the particular fiber measure, among the five included in the analysis, toward yarn strength.

Examining more carefully the results listed in table 10, it will be noted that, of the five fiber measures included, fiber strength at ⅛-inch gauge ranked strongly first in net importance to strength of 22s yarn with all three series of cottons, whereas fiber strength at the 0 gauge ranked second for both the short staple and long staple series of cottons and third with the medium staple cottons. Expressed in another way, for the short staple cottons, fiber strength at the ⅛-inch gauge explained 32.51 percent units more variance in yarn strength than did fiber strength at the 0 gauge; for the medium staple cottons, fiber strength ⅛-inch gauge accounted for 26.90 percent units more variance in yarn strength than did fiber strength 0 gauge; and for the long staple cottons, fiber strength ⅛-inch gauge explained 7.00 percent units more variance in yarn strength than did fiber strength 0 gauge. Those differences are relatively large; in fact, the differences shown for the short staple and for the medium staple cottons are outstandingly large. The difference shown with the long cottons, while more moderate in magnitude, is still appreciable.

Of the five factors, upper half mean length ranked strongly first in net importance to the strength of 22s yarn with all three staple series of cottons when fiber strength at the 0 gauge was included in the analysis, but upper half mean length ranked only second or fourth in importance to yarn strength when fiber strength at the ⅛-inch gauge was contained in the analysis. That is, when fiber strength at the ⅛-inch gauge was included in the analysis, upper half mean length explained 8.29 percent units less yarn-strength variance for the short staple cottons, 17.08 percent less for the medium staple cottons, and 16.14 percent less for the long staple cottons than it did when fiber strength at the 0 gauge was used in the analysis. Those differences are relatively large, especially for the medium and the long staple cottons; and they are highly perplexing as well as disconcerting.

For the series of short staple cottons, the micronaire measure (fiber fineness in combination with maturity) explained 5.70 percent units less variance in yarn strength when fiber strength at ⅛-inch gauge was contained in the analysis than when fiber strength at 0 gauge was included. The differences between the values for micronaire, as derived from the parallel analyses including alternative fiber strength measures, were small and negligible for the medium staple and long staple cottons.

The small difference values shown for length uniformity ratio, as derived from parallel analyses including alternative fiber strength measures, are not viewed as possessing any special meaning or significance to the objectives of this study. All six beta values for uniformity ratio toward yarn strength were statistically insignificant, each being less than three times its standard error.

The differences between parallel beta values shown for grade index also are without any particular significance in this instance, as grade index does not represent a fiber property in the generally accepted sense and as the grade factor is more or less independent of, or only incidentally associated with, cotton fiber properties.

The total beta^2 values$\times$100 shown in the last section of table 10 for the five fiber measures, including alternative fiber strength measures, reveal much of interest and value to the objectives of this study. It may be noted that, with inclusion of fiber strength at the ⅛-inch gauge, the five fiber measures explained 57.44 percent variance in yarn strength for the series of short staple cottons; that it decreased to 43.62 percent for the medium staple cottons; and that it was least for the long cottons, namely 41.72 percent. On the other hand, with inclusion of fiber strength at the 0 gauge, the five fiber measures gave total beta^2 values explaining 41.93 percent, 42.05 percent, and 49.66 percent in yarn-strength variance for the successive series of cottons.

Thus, the trends in the two sets of total beta^2 values followed opposite directions with cottons of increasing staple-length level, as influenced by the alternative measures of fiber strength used, and the ranges in their respective extreme values differed appreciably in the two cases. For example, with inclusion of fiber strength at the ⅛-inch gauge, the total beta^2 values for the five fiber measures was 57.44 percent with the series of short cottons and 41.72 percent with the long cottons, a difference of +15.72 percent units. On the other hand, with inclusion of fiber strength at the 0 gauge, the total beta^2 values for the five fiber measures was 41.93 percent with the series of short cottons and 49.66 percent with the long cottons, a difference of −7.73 percent units. In the light of these findings, it appears that not only did the total beta^2 values for the five fiber measures follow trends of opposite direction when going from short staple to medium staple to long staple cottons, depending on which alternative fiber strength measure was used in the respective analyses, but also that the range in extreme values was approximately twice as great when fiber strength at the ⅛-inch gauge was contained in the analysis as when fiber strength at the 0 gauge was included.

Referring to the difference values between the two parallel sets of total beta^2 values for the three series of cottons, as also shown in the last section of table 10, further information of interest on the comparative relationships involved is revealed. More particularly, in the case of the short staple series of cottons, 15.51 percent units more yarn-strength variance was explained by the five fiber measures when fiber strength at the

⅛-inch gauge was contained in the analysis than when fiber strength at the 0 gauge was included; for the medium staple cottons, only 1.57 percent units more yarn-strength variance was accounted for; and, for the long staple cottons, 7.94 percent units less yarn-strength variance was explained.

The foregoing series of total beta² values and comparative differences, while suggestive and helpful in furthering the objectives of this study even when standing alone, become much more meaningful and significant when they are coupled together with other types of values obtained from the respective multiple correlation analyses, as will be done in the next chapter.

EVALUATION OF TOTAL INTERACTIONS AND RESIDUALS

The comparative values for total interactions and residuals derived from the respective multiple correlation analyses, including alternative fiber strength measures and representing three series of cottons of different staple-length levels, are shown in the third section of table 11. Two other sets of values from the same correlation analyses, as previously presented and discussed, are repeated in the first and second sections of this table in order to facilitate an easy coupling together of the three different types of correlation values and to give fuller meaning to the three sets of values for purposes of this study.

In the first section of table 11, the $\bar{R}^2 \times 100$ values are listed. These values serve as a measure of the total percentage of variance in strength of 22s yarn explained by each combination of five fiber measures with each series of cottons. The $\bar{R}^2$ value, by mathematics and definition, is a function of the combined relationships, interrelationships, and interactions of all the fiber measures and factors represented in the correlation analysis. Thus, the $\bar{R}^2$ value may be either increased or decreased in varying amounts over what it would have been if no interactions had been present, depending upon the direction and degree of total effects resulting from the interactions involved.

In the second section of table 11, values for the sum of the five respective betas$^2 \times 100$ are listed. These values serve as a measure of the total percentage of variance in strength of 22s yarn explained by each combination of five fiber measures with each series of cottons, after the effects of the interrelationships and interactions have been removed. Thus, the sum of the five respective betas$^2 \times 100$ may be either smaller or larger in varying amounts than its corresponding $\bar{R}^2 \times 100$ value, depending upon the direction and degree of total effects resulting from the interactions involved.

In the third section of table 11, values representing the respective differences between $\bar{R}^2 \times 100$ and the sum of its corresponding five respective betas$^2 \times 100$ are listed. These values serve as a measure of the total amount of variance in strength of 22s yarn that is associated with the net effects of the positive and negative interrelationships and interactions existing among each combination of five fiber measures with each series of cottons.

Thus, such a value with a plus sign indicates, in percent units, the amount of increase in the magnitude of the $\bar{R}^2 \times 100$ value due to the net positive effect from the total interactions present, or the percent units to which the $\bar{R}^2 \times 100$ value exceeds what it would have been if no such interactions had been present. A difference value with a negative sign indicates, in percent units, the amount of decrease in the magnitude of the $\bar{R}^2 \times 100$ value caused by the net negative effect from the interactions involved, or the percent units to which the $\bar{R}^2 \times 100$ value is diminished below what it would have been if no such interactions had been present.

With the foregoing background of values and meanings in mind, it is of interest to examine more particularly the findings in reference to interactions and residuals, as evaluated by the respective multiple correlation analyses of this study and as reported in the third section of table 11. With five fiber measures used in the correlation analysis, including fiber strength at the ⅛-inch gauge, the exceedingly small value of −0.61 obtained with the series of short staple cottons indicates that the effect of interactions on explainable yarn-strength variance in this instance was so small as to be negligible and barely detectable. This conclusion is obvious because the value for total variance in yarn strength $\bar{R}^2 \times 100$ explained by the five fiber measures and the value for the sum of the net effects of the five fiber measures are approximately equal, the respective values being 56.83 percent and 57.44 percent.

With the series of medium staple cottons, however, using the same combination of five fiber measures in the analysis as referred to above, the interactions were of such nature and extent as to give a value of +14.29 percent; that is, they accounted for 14.29 percent units of the total yarn-strength variance explained (57.91 percent).

For the series of long staple cottons, using the same combination of fiber measures in the analysis as before, a much larger value was obtained for the

total of effects of the interactions on explainable yarn-strength variance than with the series of medium staple cottons. In this instance, it was +40.30 percent, which means that the interactions accounted for 40.30 percent units of the total yarn-strength variance explained (82.02 percent).

Thus, the three series of cottons used in this study to represent different staple-length levels showed appreciably different amounts of effects from the interactions when strength of 22s yarn was correlated with five cotton fiber measures, including fiber strength at the ⅛-inch gauge. In terms of percent units of explainable yarn-strength variance, the amounts increased more or less progressively with increase in staple-length level, the values being −0.61, +14.29, and +40.30. Expressed as a percentage of the total yarn-strength variance explained in each case ($\bar{R}^2 \times 100$), those values become −1.07, +24.68, +49.13.

Radically different results from the foregoing, however, were obtained for the interactions identified with each of the three series of cottons when the five cotton fiber measures, including fiber strength at the 0 gauge, were correlated with strength of 22s yarn. For the series of short staple cottons, the net effect from the combined interactions aggregated a total of −19.79 percent units of yarn-strength variance, which indicates the presence and operation among the factors of a relatively large amount of negative effects from the interrelationships and interactions involved. The total variance in yarn strength explained by this combination of factors was exceedingly small, being the smallest by far of all such values obtained from the six multiple correlation analyses of this study. The $\bar{R}^2 \times 100$ value in this instance was only 22.14 percent, as compared with 56.83 percent for the same series of short staple cottons when the correlation analysis included fiber strength at the ⅛-inch gauge among the five fiber measures used.

In the light of the foregoing values, it appears that the total amount of yarn-strength variance ($\bar{R}^2 \times 100$) explained by the five fiber measures for the short staple cottons was depressed severely by the relatively strong or dominating negative effects from the interactions operating in the analysis containing fiber strength at the 0 gauge. Thus, if there had been no negative effects from the interactions in this case, or if there had been sufficient positive effects to offset the negative effects, the total yarn-strength variance explained by the combined factors would be expected to be 41.93 percent and not 22.14 percent (22.14+19.79).

For the series of medium staple cottons, the effects from the interactions identified with the five fiber measures, including fiber strength at the 0 gauge, on yarn-strength variance were negligible, amounting only to −0.93 percent units.

But, for the series of long staple cottons, the effects of the interactions associated with the same combination of five fiber measures were strongly positive toward the variance in yarn strength explained by the factors, as indicated by the value +33.97 percent. This means that 33.97 percent units of the total yarn-strength variance explained under this set of conditions was due to the effects of the interactions involved. This also means that, if no such total of positive effects arising from the interactions had been present, or if the positive and negative effects had been equal, the total variance in yarn strength explained would have been only 49.66 percent and not 83.63 percent (83.63−33.97).

Thus, the three series of cottons representing different staple-length levels showed appreciably different proportions of effects from the interactions when strength of 22s yarn was correlated with five cotton fiber measures, including fiber strength at the 0 gauge. In terms of percent units of explainable yarn-strength variance, the amounts increased rather progressively with increase in staple-length level, the values being −19.79, −0.93, and +33.97. Expressed as a percentage of the total yarn-strength variance explained in each case ($\bar{R}^2 \times 100$), those values become −89.39, −2.26, +40.62.

While the respective percentages of interactional effects toward variance in strength of 22s yarn increased more or less progressively with increase in staple length level for both combinations of five cotton fiber measures, including alternative fiber strength measures, the two series of values occupied appreciably different levels. With the analyses that include fiber strength at the ⅛-inch gauge, the percentages were −0.61, +14.29, and +40.30 for the short, medium, and long cottons; with the analyses that include fiber strength at the 0 gauge, the percentages were −19.79, −0.93, and +33.97. This difference in level is further emphasized by the difference values representing the interactions identified with the alternative combinations of five fiber measures for each series of cottons, as shown in the last column of the last section of table 11. As may be seen there, in terms of yarn-strength variance, the values obtained from the respective analyses including fiber strength at the ⅛-inch gauge were larger than those from the respective analyses including fiber strength at the 0 gauge by the following amounts: +19.18 percent units for the short staple cottons, +15.22 percent units for the medium staple cottons, and +6.33 percent units for the long staple cottons.

EVALUATION OF FIBER-MEASURE INTERRELATIONSHIPS

Variation in the amount and direction of total interactions and residuals associated with the alternative groups of five fiber measures in relation to explainable yarn-strength variance representing cottons of different staple-length levels, as discussed in the previous chapter, constitutes the heart of this complex problem. However, as interesting and suggestive as those reported values are for the total multifactorial interactions and residuals toward explainable yarn-strength variance, they need to be further explored and translated into values representing the interrelationships existing between the fiber measures involved, as identified with each of the three series of cottons studied. Such a course of detailed investigation is needed in the effort being made to resolve this intricate problem in terms of its basic components.

Fifteen Pairs of Fiber Measures, Including Both Fiber Strength Measures

By using four fiber measures in conjunction with alternative fiber strength measures in the multiple correlation analyses, a total of six cotton fiber measures per series of cottons is involved. Six cotton fiber measures allow a total of 15 possible pairs of fiber measures $\left(\frac{6\times5}{2}\right)$. Accordingly, simple correlation analyses were made with the data representing each of the 15 pairs of fiber measures for each of the three series of cottons of different staple-length levels.

A summary of the values for the respective coefficients of simple determination ($r^2\times100$) is shown in table 12, the pairs of fiber measures being listed in descending order of values for the series of short staple cottons. The number shown in parentheses with each value indicates the rank of the correlation coefficient, in descending order, among the 15 coefficients obtained with each series of cottons.

The first sign listed with each value in table 12 indicates the direction of the relationship between the respective pairs of fiber measures. That is, if the values of any two fiber measures move in the same direction, the relationship is positive and the sign is plus; if they move in opposite directions, the relationship is negative and the sign is minus.

The second sign (shown in parentheses) with each value listed in table 12 indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the two beta coefficients for the respective factors toward yarn strength. The direction of the effect of the interrelationship between any two fiber measures on yarn strength may be either positive or negative, depending on the circumstances revealed by this analytical treatment. And, the sign shown in parentheses for the directional effect of the interrelationship toward yarn strength may be the same as or opposite to the corresponding sign for the direction of the correlation existing between the two fiber measures.

Examination of the values listed at the bottom of table 12 reveals that the 15 pairs of fiber measures show the smallest total amount of interrelationships positive toward yarn strength for short staple cottons and that the values increase markedly with increase in staple-length level of the cottons, as shown by the successive values of +25.40 percent, +49.83 percent, and +182.89 percent. The trend, however, is opposite for total fiber-measure interrelationships negative toward yarn strength, the largest value by far having been obtained with the short staple cottons, namely, −84.35 percent. The values for the fiber-measure interrelationships negative toward yarn strength are very small and more or less negligible, the values being only −5.99 percent for the medium staple and −3.47 percent for the long staple series.

When the total fiber-measure interrelationships positive and negative toward yarn strength are considered in conjunction with each other, the net values obtained for the three series of cottons are as follows: short staple cottons, −58.95 percent; medium staple cottons, +43.84 percent; and long staple cottons, +179.42 percent. Thus, there is a strong upward trend in directional net values of fiber-measure interrelationships toward yarn strength with increasing staple-length level of the groups of cottons studied, the overall difference between the short staple and long staple series of cottons being 238.37 percent units, +179.42−(−58.95). The step between the values for short staple and medium staple cottons is 102.79 percent units, +43.84−(−58.95), and the step between the values for medium staple and long staple cottons is 135.58 percent units, +179.42−(+43.84).

Of particular interest in connection with the foregoing values is the fact that the directional net values for total interrelationships toward yarn strength, representing 15 possible pairs of six fiber measures, is so strongly negative in the case of the short staple cottons (−58.95 percent), so strongly positive with the long staple cottons (+179.42 percent), and intermediate on the positive side with the medium staple cottons (+43.84 percent). Such appreciably different amounts and opposite directions of interrelationships toward yarn strength, which exist between those fiber measures when applied to cottons of different staple-length levels, suggest what is present and

operating more or less in all multiple and simple correlation analyses pertaining to cotton fibers and why so many of the correlation results obtained in the past have been inconsistent, surprising, and unexplainable.

Ten Pairs of Fiber Measures, Including Fiber Strength at the ⅛-Inch Gauge

The foregoing values characterize the three series of cottons of different staple-length levels in terms of 15 pairs of fiber measures representing six fiber measures, including both fiber strength measures. They do not supply a basis as such, however, for explaining the principal variations, disparities, and inconsistencies shown by the results obtained from the multiple correlations of this study, as presented earlier in this report. Those correlation analyses included five fiber measures, using the alternative fiber strength measures in parallel analyses, so each analysis represented interrelationships aggregating a total of only 10 possible pairs of five fiber measures $\left(\frac{5\times4}{2}\right)$.

Values for the coefficients of simple determination ($\bar{r}^2\times100$) are listed in table 13 for the 10 pairs of fiber-measure interrelationships involved when fiber strength at the ⅛-inch gauge was used with each of the three series of cottons. The pairs of fiber measures are listed and ranked in each case, together with signs showing the direction of the interrelationships between the paired fiber measures and the direction of the contribution of the paired interrelationships toward yarn strength, as was done in table 12.

For the series of short staple cottons, only one interrelationship was statistically significant, five were statistically insignificant, and four were zero. For the medium staple cottons, three interrelationships were statistically significant, five were statistically insignificant, and two were zero. And, for the long staple cottons, seven interrelationships were statistically significant, two were statistically insignificant, and one was zero.

The values shown in table 13 for the total positive fiber-measure interrelationships involved toward yarn strength, for the total negative toward yarn strength, and for the net differential toward yarn strength, representing the three series of cottons of different staple-length levels, possess particular interest when considered in connection with the results obtained from the corresponding multiple correlation analyses presented earlier in this report. The interrelationship values varied appreciably over a wide range from the short staple to the medium staple to the long staple cottons, as revealed by comparison of the successive values shown in table 13. The total of all fiber-measure interrelationships (without regard to direction toward yarn strength) increased with increasing staple-length levels of the cottons as follows: 34.78, 40.08, 115.95 percent.

Total fiber-measure interrelationships positive toward yarn strength increased markedly with increasing staple-length level, as indicated by the following: +5.30, +35.19, +112.48 percent. On the other hand, total interrelationships negative toward yarn strength decreased with increasing staple-length level, as follows: −29.48, −4.89, −3.47 percent. The directional net values for the interrelationships toward yarn strength, with due regard to the total positive and negative values, are as follows: short staple cottons, −24.18 percent; medium staple cottons, +30.30 percent; and long staple cottons, +109.01 percent. These values differ appreciably and cover a wide range, the overall range being 133.19 percent units. The step between the values for short staple and medium staple cottons is 54.48 percent units and the step between the medium staple and long staple cottons is 78.71 percent units.

Ten Pairs of Fiber Measures, Including Fiber Strength at the 0 Gauge

Parallel results are listed in table 14 for the interrelationships existing among the 10 pairs of fiber measures which were present and contributing in the multiple correlation analyses identified with fiber strength at the 0 gauge. For the series of short staple cottons, three of the interrelationships were statistically significant (two of which were very strongly negative toward yarn strength), five were statistically insignificant, and two were zero. For the medium staple cottons, only one of the interrelationships was barely statistically significant, six were statistically insignificant, and three were zero. And, for the long staple cottons, six of the interrelationships were statistically significant, three were statistically insignificant, and only one was zero.

The total of all fiber-measure interrelationships (without regard to direction toward yarn strength) was least with the medium staple cottons, much larger with the long staple cottons, and still larger with the short staple cottons, as revealed by the respective values of 14.11, 71.51, and 102.23 percent. The total of the fiber-measure interrelationships positive toward yarn strength was least with the medium staple cottons (+8.12 percent), slightly larger with the short staple cottons (+17.88), and very much larger with the long staple cottons (+68.04).

But, for total fiber-measure interrelationships negative toward yarn strength, the values decreased with increasing staple-length level of the cottons, being outstandingly large in the case of the short staple cottons (−84.35 percent), and small or negligible with the medium staple (−5.99) and with the long staple cottons (−3.47).

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The directional net values for the fiber-measure interrelationships toward yarn strength, as based on the total positive and negative values in combination, are as follows: short staple cottons, —66.47 percent; medium staple cottons, +2.13 percent; and long staple cottons, +64.57 percent.

The foregoing findings in reference to the amount and direction of total interrelationships toward yarn strength, as identified with the three series of cottons of different staple-length levels, are radically different in many respects, depending on whether fiber strength at the ⅛-inch gauge or fiber strength at the 0 gauge was used in the respective analyses. The pattern unfolded herewith for the fiber-measure interrelationships and their directional effect toward yarn strength, moreover, follows rather closely the pattern of results obtained from parallel sets of multiple correlation analyses, including the alternative fiber strength measures, as previously presented in this report. Obviously, therefore, these findings on fiber-measure interrelationships and their probable effects on explainable yarn-strength variance are matters of much interest and importance to cotton-quality evaluations in general and to the interpretation of related results from correlation analyses in particular. The question of fiber-measure interrelationships, however, can and should be explored further as is done in the following pages.

Four Pairs of Fiber Measures Identified with Fiber Strength at the ⅛-inch Gauge

As previously explained, the respective multiple correlation analyses with yarn strength considered in this report contained interrelationships representing 10 pairs of fiber measures. Of these, four were identified with fiber strength at the ⅛-inch gauge, four with fiber strength at the 0 gauge, and six were independent of both fiber strength measures. It is of interest to the objectives of this study, therefore, to examine the interrelationships embraced by those more limited and specific combinations of factors.

In table 15, values for the fiber-measure interrelationships identified with the alternative fiber strength measures are listed. With fiber strength at the ⅛-inch gauge, as listed in the upper part of that table, the short staple cottons showed only one pair of fiber measures to have any degree of interrelationship and it was extremely small, barely detectable, and statistically insignificant. The other three pairs of measures exhibited zero interrelationships. For the medium staple cottons, two of the interrelationships were statistically significant, one was insignificant, and one was zero. And, for the long staple cottons, all four interrelationships were statistically significant.

Total fiber-measure interrelationships connected with fiber strength at the ⅛-inch gauge and positive toward yarn strength increased appreciably with increase in staple-length level of the cottons, as shown by the values of +2.27 percent for the short cottons, +29.45 percent for the medium, and +75.42 percent for the long. It is of special interest to note that there were *no* interrelationships negative toward yarn strength with fiber strength at the ⅛-inch gauge for all three series of cottons of different staple-length levels. On the basis of the findings with these factors, fiber strength at the ⅛-inch gauge appears to be a relatively "pure" measure of fiber strength for short staple cottons. But, fiber strength at the ⅛-inch gauge is an increasing complex in the positive direction toward yarn strength, with increasing staple-length level of cottons, and it appears to become less pure as a measure of fiber strength with increasing staple-length level.

Four Pairs of Fiber Measures Identified With Fiber Strength at the 0 Gauge

The fiber-measure interrelationships associated with fiber strength at the 0 gauge, as reported in the lower part of table 15, are radically different in many respects from those shown in the upper part of the same table for fiber strength at the ⅛-inch gauge. With fiber strength at the 0 gauge, the short staple cottons showed two pairs of fiber measures to have interrelationships of statistical significance, one pair was insignificant, and one pair was zero. The combined interrelationships in this instance, however, were strongly negative toward explainable yarn-strength variance, the only case that such was observed in this entire study. For the medium staple cottons, two of the fiber-measure interrelationships were statistically insignificant and two of them were zero. And, for the long staple cottons, three fiber-measure interrelationships were statistically significant and one was insignificant.

The total of all fiber-measure interrelationships (without regard to direction toward yarn strength), as identified with fiber strength at the 0 gauge, was least in the case of the medium staple cottons (3.48 percent), considerably larger with the long staple cottons (30.98), and very much larger with the short cottons (69.72 percent). The total of the fiber-measure interrelationships positive toward yarn strength was least with the medium staple cottons (+2.38 percent), slightly larger with the short staple cottons (+14.85), and considerably larger for the long staple cottons (+30.98 percent).

But, for total fiber-measure interrelationships associated with fiber strength at the 0 gauge and negative toward yarn strength, the value was outstandingly large with the short staple cottons (—54.87 percent), barely detectable and negligible with the medium staple cottons (—1.10), and zero

with the long staple cottons. The directional net values for the interrelationship toward yarn strength, as based on the total positive and negative values in combination, are as follows: short staple cottons, −40.02 percent; medium staple cottons, +1.28 percent; and long staple cottons, +30.98 percent.

On the basis of the results with these factors, fiber strength at the 0 gauge seems to be a relatively "pure" measure of fiber strength in the case of the medium staple cottons. But, with the short staple cottons, fiber strength at the 0 gauge appears to be an extremely complex measure by reason of its high degree of negative fiber-measure associations in reference to yarn strength. Thus, when fiber strength at the 0 gauge test is applied to short staple cottons, it would seem to be far from being a pure measure of fiber strength. These conclusions are strongly supported, moreover, by the unfavorable results obtained from the multiple correlation analysis with fiber strength at the 0 gauge and the series of short staple cottons, as considered earlier in this report.

On the other hand, for long staple cottons, fiber strength at the 0 gauge is a complex in the positive direction, but not to as high a degree as fiber strength at the ⅛-inch gauge.

Six Pairs of Fiber Measures Independent of Both Fiber Strength Measures

The four pairs of fiber-measure interrelationships identified with each fiber strength at the ⅛-inch gauge and with fiber strength at the 0 gauge, as considered in the foregoing, reflect the dominating or controlling interrelationships and their directional effects which were operating in the multiple correlation analyses with yarn strength, including alternative fiber strength measures, for each series of cottons, as previously covered in this report. Such is more particularly true by reason of the fact that the remaining six pairs of interrelationships involved in the parallel correlation analyses with each series of cottons were common to both analyses. It is of interest to the objectives of this study, nevertheless, to examine the interrelationship findings that have been obtained for this group of fiber measures.

In table 16, a summary of the coefficients of simple determination ($\bar{r}^2 \times 100$) representing the interrelationships between the six pairs of fiber measures independent of both fiber strength measures is shown. The total of these fiber-measure interrelationships positive toward yarn strength was small and negligible in the case of the short staple cottons (+3.03 percent) as well as of the medium staple cottons (+5.74), but it was considerably larger for the long staple cottons (+37.06 percent). On the other hand, the total of these fiber-measure interrelationships negative toward yarn strength was relatively large with the short staple cottons (−29.48 percent), but only small and negligible for the medium staple (−4.89) and long staple cottons (−3.47 percent).

The net directional amounts of interrelationships toward yarn strength, arising from the six pairs of fiber measures independent of both fiber strength measures, were as follows: short staple cottons, −26.45 percent; medium staple cottons, +0.85 percent; and long staple cottons, +33.59 percent.

ESTIMATION OF EFFECTS FROM FIBER-MEASURE INTERRELATIONSHIPS

In the previous chapter, values were presented for the total positive, for the total negative, and for the net total of positive or negative interrelationships existing between the 10 pairs of each combination of 5 fiber measures, as included in each multiple correlation analysis with strength of 22s yarn, for each series of cottons representing different staple-length levels. Corresponding values also were presented in the previous chapter for the four pairs of interrelationships identified with fiber strength at the ⅛-inch gauge, for the four pairs of interrelationships in connection with fiber strength at the 0 gauge, and for the six pairs of interrelationships independent of both fiber strength measures, representing each series of cottons.

The foregoing values pertaining to interrelationships are highly interesting for what they suggest toward explaining the pattern of divergent results ($\bar{R}$, $\bar{R}^2$, and betas) obtained from the respective multiple correlation analyses, as considered earlier in this report. More particularly, those interrelationship findings are valuable for what they suggest toward explaining the pattern of divergent results obtained for the total interactions and residuals from the respective multiple correlation analyses, as previously considered in this report; and toward finding out the way in which and the extent to which the interrelationships existing among the various fiber measures influenced the total interactions and residuals reported for the alternative groups of factors when correlated with yarn strength representing each series of cottons of different staple-length levels.

But, when standing alone, the values for the fiber-measure interrelationships can not fulfill

such purposes by reason of the fact that they refer only to the degree of associated variance existing between the respective pairs of fiber measures in their directional relation toward yarn strength. That is, those values do not have any precise meaning in terms of explainable yarn-strength variance. Thus, in order to provide the information needed, the interrelationship values have to be translated or converted, by some method, into terms of explainable yarn-strength variance. That hurdle, in fact, constitutes the major crux and principal difficulty involved in this study.

In an effort to develop more precise meaning for the total interactions and residuals identified with each combination of fiber measures for each series of cottons, in terms of evaluated interrelationships existing among the fiber measures, estimates have been made by a series of unique but somewhat devious and laborious analytical procedures which were devised for coupling together various associated correlation values and signs, and for weighting their respective combinations and effects in terms of explainable variance in skein strength of 22s carded yarn. Insofar as it is known, this is the first time that such a method of analysis has been applied to cotton fiber data and correlation values.

The method used herein for estimating the effect of fiber-measure interrelationships on explainable variance in strength of 22s yarn was as follows: For each pair of fiber measures involved with each of the three series of cottons, the two corresponding beta values were added together; their sum was squared and multiplied by 100; this value was multiplied by the coefficient of simple determination ($\bar{r}^2$) representing the degree of interrelationship existing between the pair of fiber measures under consideration; and this calculated product was given the sign denoting the direction of the effect of yarn-strength variance from the interrelationship identified with the particular pair of fiber measures, as shown in previous tables.

The process described above was repeated for each of the 10 pairs of fiber measures included in each multiple correlation analysis; the 10 values were added together, due regard being given to their respective signs; and the total positive or negative value obtained was accepted as being the estimated total or combined net effect of the 10 pairs of fiber interrelationships on the amount of yarn-strength variance explained by the combination of 5 fiber measures for a particular series of cottons. The estimated total value so derived may be verified by comparison with the value for total interactions and residuals calculated from the corresponding multiple correlation analysis ($\bar{R}^2 \times 100 - 5\ \text{betas}^2 \times 100$).

In certain respects, however, the estimated values for the effects of individual pairs of fiber interrelationships on yarn-strength variance offer advantages over that shown by the one value for total interactions and residuals. That is, the value for total interactions and residuals includes—among other things—the combined or overall effects arising from the 10 individual pairs of fiber measures represented in the multiple analysis. On the other hand, as the estimated values are identified with the respective pairs of fiber measures, individual comparisons of the paired effects may be made for the series of cottons representing different staple-length levels. Moreover, the estimated values may be grouped together to show the effect on yarn-strength variance of the four pairs of factors identified with fiber strength at the ⅛-inch gauge, of the four pairs of factors identified with fiber strength at the 0 gauge, and of the six pairs of factors independent of both fiber strength measures. Obviously, such compositional breakdowns are impossible with the single value for total interactions and residuals, as calculated from certain results furnished by conventional multiple correlation analysis.

In the middle part of table 17, comparative values are listed for the estimated percentages of variance in skein strength of 22s yarn explained by the 4 pairs of interrelationships identified with fiber strength at the ⅛-inch gauge, by the 6 pairs of fiber-measure interrelationships independent of fiber strength, and by the combined 10 pairs of fiber measures involved in each multiple correlation analysis with the 3 series of cottons representing different staple-length levels. As background information for assistance in calculating those estimates, the percentages of fiber-measure interrelationships toward yarn strength for each group of factors are shown in the upper part of the table. And, for purposes of comparison, the values representing total interactions and residuals derived from each multiple correlation analysis are listed in the lower part of the table.

It will be seen in table 17 that the interrelationships identified with fiber strength at the ⅛-inch gauge accounted for only +1.01 percent units of explainable yarn-strength variance for the short staple cottons, +16.6 percent for the medium staple cottons, and +39.70 percent for the long staple cottons. Thus, the amount of yarn-strength variance explained by the fiber-measure interrelationships identified with fiber strength at the ⅛-inch gauge increased appreciably with increase in staple-length level of the cotton studied, being negligible for the short staple cottons, moderate for the medium staple cottons, and outstandingly large for the long staple cottons.

As also noted in table 17, the fiber-measure interrelationships independent of fiber strength at the ⅛-inch gauge exerted a small degree of influence on the evaluated amount of explainable yarn-strength variance but their total effects were negative for short staple (−2.85 percent units) and medium staple cottons (−0.11) and positive

for the long staple cottons (+5.15). Thus, the interrelationships independent of fiber strength at the ⅛-inch gauge also showed an upward trend in effects on explainable yarn-strength variance with increasing staple-length level of the cottons.

Adding together the respective values shown in the two foregoing series, totals of which are listed in table 17, the interrelationships representing the 10 pairs of fiber measures influenced the amount of explainable yarn-strength variance as follows: −1.84 percent units for the short staple cottons, +16.05 percent for the medium staple cottons, and +44.85 percent for the long staple cottons. Thus, in the multiple correlation analyses containing five fiber measures, including fiber strength at the ⅛-inch gauge, there was a strong upward trend—with increasing staple-length level of the cottons—in the magnitude of total effect from all the fiber-measure interrelationships involved on the amount of yarn-strength variance explained.

It will also be seen in table 17, that the values for total interactions and residuals obtained from the respective multiple correlation analyses with the different series of cottons were as follows: −0.61 percent units for the short staple cottons, +14.29 percent for the medium staple cottons, and +40.30 percent for the long staple cottons. Thus, the values for total interactions and residuals follow a similar pattern with the successive series of cottons to that for the estimated values for total effect of all 10 pairs of fiber-measure interrelationships involved, as considered above. Moreover, all things considered, the two sets of values are viewed as being remarkably close in agreement, as indicated by the small difference values shown at the bottom of table 17.

In the middle part of table 18, values are listed for the estimated percentages of yarn-strength variance explained by the 4 pairs of fiber-measure interrelationships identified with fiber strength at the 0 gauge, by the 6 pairs of fiber measures independent of fiber strength at the 0 gauge, and by the total 10 pairs of fiber measures involved in each analysis with cottons of different staple-length levels. Values are also listed in the upper part of that table for the percentages of fiber-measure interrelationships toward yarn strength for each group of factors, together with a listing in the lower part of the table of values for total interactions and residuals as obtained from the respective multiple correlation analyses.

The results listed in table 18 from the analyses containing fiber strength at the 0 gauge differ markedly in certain respects from the corresponding values in reference to fiber strength at the ⅛-inch gauge which were shown in table 17. More particularly, the fiber-measure interrelationships identified with fiber strength at the 0 gauge were strongly negative in the case of the short staple cottons, causing a decrease in the amount of explainable yarn-strength variance for those cottons to the extent of −13.98 percent units. For the medium staple cottons, the fiber-measure interrelationships associated with fiber strength at the 0 gauge were barely detectable with a positive tendency, as indicated by the small value of +0.66 percent. And, for the long staple cottons, the fiber-measure interrelationships identified with fiber strength at the 0 gauge increased the amount of explainable yarn-strength variance by +13.73 percent units.

Thus, with increasing staple-length level of the cottons, there was an appreciable upward trend in the scale of effects from the interrelationships identified with fiber strength at both the 0 gauge and the ⅛-inch gauge on explainable yarn-strength variance. There was, however, one significant and important difference between the two sets of values: The effects from the fiber-measure interrelationships associated with fiber strength at the 0 gauge toward explainable yarn-strength variance, representing the three series of cottons of different staple-length levels, were on an appreciably lower level than those for the corresponding effects from the interrelationships connected with fiber strength at the ⅛-inch gauge. The average difference between corresponding values for the three series of cottons was 18.82 percent units, the respective differences being as follows: for the short staple cottons, 14.99 percent; for the medium staple cottons, 15.50 percent; and for the long staple cottons, 25.97 percent.

As shown in table 18, the effects on explainable yarn-strength variance resulting from the interrelationships connected with the six pairs of fiber measures independent of fiber strength at the 0 gauge were smaller than those connected with the four pairs of interrelationships identified with this fiber strength measure. The series of values showed an upward trend with increasing staple-length level of the cottons, as indicated by the following values: −5.87 percent units for the short staple cottons; +0.43 percent for the medium staple cottons; and +11.57 percent for the long staple cottons.

Also, as shown in table 18, the total effects of the interrelationships representing the 10 pairs of fiber measures, including fiber strength at the 0 gauge, influenced the amount of explainable yarn-strength variance, as follows: −19.85 percent units for the short staple cottons; +1.09 percent units for the medium staple cottons; and +25.30 percent units for the long staple cottons. These values compare favorably with those obtained for total interactions and residuals from the respective multiple correlation analyses, which are also listed in table 18 as follows: −19.79 percent units for the short staple cottons; −0.93 percent units for the medium staple cottons; and +33.97 percent units for the long staple cottons. The two sets of values follow the same definite pattern with increasing staple-length level of the

cottons, and the corresponding values for each series of cottons agree closely, except for the long staple cottons where there was a disparity of −8.67 percent units. This is the largest disparity in percent units of explainable yarn-strength variance that was observed with the six cases included in this study, but why it was so, or should be so, is not known at this time.

The values listed in tables 17 and 18 have been regrouped in the next three tables to permit an easy and more direct comparison of the fiber-measure interrelationships involved, their estimated effects on explainable yarn-strength variance, and the total interactions and residuals furnished by the respective multiple correlation analyses, as identified with fiber strength at the ⅛-inch gauge versus fiber strength at the 0 gauge. The comparative sets of values and differences are listed in table 19 for the series of short staple cottons, in table 20 for the medium staple cottons, and in table 21 for the long staple cottons. The observed and differential values shown in those three tables are self-explanatory and, as they already have been considered in substantial part, they will not be considered here in further detail.

On the basis of the comparative findings presented in tables 17, 18, 19, 20, and 21, it is concluded that the estimated values for the total effect of the 10 pairs of interrelationships on explainable yarn-strength variance, representing five fiber measures and including alternative fiber strength measures, agree as well as could be expected with the corresponding values for total interactions and residuals furnished by the respective multiple correlation analyses for the three series of cottons representing different staple-length levels. Perfect agreement should never be expected between parallel results obtained by such correlation and estimation methods, as necessarily were involved in these cases, especially when the conditions being evaluated represent the outcome from such a vast interplay of so many factors and forces, including both cumulative and compensative effects in diverse ways and degrees, and involving both positive and negative influences in various ways and degrees. While the coupling, weighting, and estimating procedures employed for this purpose are the best that it has been possible to develop to date, the disparities between the values obtained by correlation and by estimation may indicate that the method of estimation oversimplifies the problem.

In this connection, it also should be remembered that many more fiber properties actually were involved in the yarn-strength variance considered herein than were, or could be, included in these analyses. Moreover, the fiber measures used in this study, while having been improved and standardized to a relatively high degree, possessed limitations of various sorts and cannot be considered as being perfect for their intended purposes. In addition, unavoidable and more or less normal errors of measurement were ever present in connection with the fiber and yarn-strength tests. And, finally, the cottons of each staple length series were carded at different rates of production (12½ pounds per hour for short staple, 9½ p.h. for medium staple, and 6½ p.h. for long staple) and the yarns for each staple-length series possessed somewhat different amounts of twist, generally fewer turns per inch with increasing staple-length level of the cotton. All of these varying factors and intangible conditions exert effects on the end results furnished by the correlation analyses and by the devious methods of estimation. Evaluation of these factors is complicated by the presence of so many positive and negative effects as well as so many cumulative and compensative effects.

Yet, in spite of all the intangibles, limitations, and complexities referred to above, the findings presented in tables 17, 18, 19, 20, and 21 constitute a sizable and rather consistent mass of evidence to the effect that most (except for 1 case out of 6) of the varying amounts of positive or negative interactions and residuals shown by the respective multiple correlation analyses was due to the net effects of the total positive and negative interrelationships existing between the 10 pairs of fiber measures involved in each case. Moreover, on the basis of those results together with others presented in previous tables, it would appear that the total net effects of the 10 pairs of fiber-measure interrelationships influenced appropriately, according to the established pattern of their estimated effects, all values obtained from the respective multiple correlation analyses.

In particular, as based on the findings reported in tables 17, 18, 19, 20, and 21, it would again appear that fiber strength at the ⅛-inch gauge was a relatively "pure" measure of fiber strength in this group of factors with this series of short staple cottons but that it was, in effect, a complex with appreciably increasing positive effects toward explainable yarn-strength variance with increasing staple-length level of the cottons. On the other hand, in decided contrast, it would again appear that fiber strength at the 0 gauge was a comparatively "pure" measure of fiber strength with this group of factors for this series of medium staple cottons but that it was, in effect, a complex with appreciable negative effects toward explainable yarn-strength variance in the short staple cottons and with pronounced positive effects toward explainable yarn-strength variance in the long staple cottons.

The positive effects of the interrelationships associated with fiber strength at the 0 gauge on explainable yarn-strength variance in the long staple cottons (+13.73 percent units) amounted only to about one-third of that connected with fiber strength at the ⅛-inch gauge for the same

series of cottons (+39.70 percent units). From this, it may be concluded that fiber strength at the 0 gauge was a "purer" measure of fiber strength with this group of factors for this series of long staple cottons than was fiber strength at the ⅛-inch gauge. Presumably, such would hold more or less with all series of commercial long staple American upland cottons currently available, and probably with commercial long staple Egyptian and American Egyptian cottons currently available.

In tables 19, 20, and 21, attention is called to the fact that the values reported for the estimated effects of the six pairs of fiber-measure interrelationships independent of both fiber strength measures were different, depending on whether fiber strength at the ⅛-inch gauge or fiber strength at the 0 gauge was included in the multiple correlation analysis. Those apparent disparities arise from the method used in calculating the estimated effects of the interrelationships and they are, by circumstances, unavoidable. That is, the respective beta values used in the weighting process for deriving the estimated effects of the six pairs of fiber-measure interrelationships independent of fiber strength differed somewhat, depending on which fiber strength measure was used in the multiple correlation analysis. For the parallel analyses with each series of cottons, the beta values for the factors concerned were generally smaller when fiber strength at the ⅛-inch gauge was included in the correlation analysis than when fiber strength at the 0 gauge was used. Apparently, therefore, fiber strength at the ⅛-inch gauge was a stronger and more dominating factor in these multiple correlation analyses than was fiber strength at the 0 gauge, a condition which presumably caused the beta values for the other factors involved in the complex and sensitive balance to be influenced accordingly. This finding also may be taken to suggest that the beta coefficient as a measure of the relative net effect of an independent variable on a dependent variable may not be entirely free from the effects of all possible fiber-measure interrelationships. This matter is discussed further in a later chapter of this report entitled "Net Effects: Beta Coefficients Versus Partial Correlation Coefficients."

EVALUATION OF GROSS EFFECTS

The values representing the relative gross importance of individual cotton fiber measures to a dependent variable, such as yarn strength, are generally thought of as being larger than the corresponding values representing their relative net importance. This generalization is assumed primarily because the evaluations of the relative gross effects are known to have ignored the effects of all of the interactions and interrelationships present and operating in the respective simple correlation analyses, whereas the evaluations of their relative net effects are known to have taken into account all, or a high proportion, of the effects of the interactions and interrelationships involved in the multiple analysis. While the view generally held is true in most cases, it presupposes that all the fiber-measure interrelationships and contributing effects toward the dependent variable are positive, or that the total positive exceed the total negative interrelationships and contributing effects.

A previous chapter of this publication reported total interactions and residuals as evaluated by the respective multiple correlation analyses on yarn strength with five cotton fiber measures, including alternative fiber strength measures. Since those results differed so much for the two combinations of fiber measures when used with cottons of different staple-length levels, it seemed desirable to make a complete set of simple correlation analyses for evaluating the gross importance of the six respective fiber measures toward yarn strength and for providing another comparative basis of assistance to the study of this fiber-measure interrelationship problem. This investigative approach was further prompted by the pattern of positive and negative effects of the fiber-measure interrelationships toward explainable yarn-strength variance, as identified with the 10 pairs of fiber measures representing each combination of 5 fiber measures and each series of cottons, and as established in previous chapters of this report. Of interest, therefore, is the direction and degree to which such fiber-measure interrelationships may influence the results from this series of simple correlation analyses.

A summary of the coefficients of simple correlation ($\bar{r}$) and of the coefficients of simple determination ($r^2 \times 100$) showing the relative gross importance of five fiber measures toward skein strength of 22s yarn, representing the three series of cottons of different staple-length levels, is presented in table 22 with inclusion of fiber strength at the ⅛-inch gauge and in table 23 with inclusion of fiber strength at the 0 gauge. Of the five fiber measures listed in table 22, fiber strength at the ⅛-inch gauge ranked first in importance to yarn strength and upper half mean length ranked second with all series of cottons. But, of the five fiber measures listed in table 23, upper half mean

length ranked first in importance to yarn strength with all series of cottons, and fiber strength at the 0 gauge ranked either second or third. These ranks of gross importance are in general line with those reported previously for net importance (beta values). Most of the corresponding gross and net values, however, show appreciably different levels of magnitude.

In table 24, the values listed in tables 22 and 23 for coefficient of simple determination are regrouped to permit a direct comparison of the parallel values identified with fiber strength at the ⅛-inch gauge versus fiber strength at the 0 gauge. It will be noted that, on the basis of the $r^2 \times 100$ values, fiber strength at the ⅛-inch gauge—together with all the other fiber properties associated with it in disguise—explained 42.61 percent of the yarn-strength variance for the short staple cottons, 49.41 percent with the medium staple cottons, and 69.90 percent with the long staple cottons. Thus, the evaluated gross contribution of fiber strength at the ⅛-inch gauge to yarn strength increased appreciably with increase in staple length of the cottons.

The gross contribution of fiber strength at the 0 gauge to yarn-strength variance, on the other hand, was zero with the short staple cottons, only 6.07 percent with the medium staple cottons, and 47.07 percent within the long staple cottons. Here again there was a strong upward trend in the evaluated gross importance of fiber strength at the 0 gauge to yarn strength with increasing staple-length level of the cottons. But, the respective amounts of the contribution of fiber strength at the ⅛-inch gauge to yarn-strength variance were on a decidely higher level than those for fiber strength at the 0 gauge, the differences of explainable yarn-strength variance in favor of fiber strength at the ⅛-inch gauge being as follows: +42.61 percent units with the short staple cottons, +43.34 percent units with the medium staple cottons, and +22.83 percent units with the long staple cottons. These serial and differential values for the alternative fiber strength measures toward yarn strength variance are in general line with the beta values previously reported for their respective net effects, in combination with the effects of the fiber-measure interrelationships involved.

As to the gross contributions of the other four fiber measures to yarn-strength variance, they increased in amount with increasing staple-length levels of the cottons, as indicated by the following: Upper half mean length ranged from 11.38 percent with the short staple cottons to 52.14 percent with the long staple cottons; micronaire, from zero to 15.64 percent; length uniformity ratio, from zero to 10.58 percent; and grade index, from zero to 28.90 percent.

For the five fiber measures, including fiber strength at the ⅛-inch gauge, their total gross contributions in terms of yarn-strength variance were as follows: 53.99 percent in the case of the short staple cottons, 82.07 percent with the medium staple cottons, and 177.16 percent with the long staple cottons. The total gross contributions for the five fiber measures, including fiber strength at the 0 gauge, were 11.38 percent for the short cottons, 38.73 percent for the medium, and 154.33 percent for the long cottons. The serial differences between the total contributions to yarn-strength variance for the five fiber measures, including the alternative fiber strength measures, were the same as those previously reported in favor of fiber strength at the ⅛-inch gauge; namely, +42.61 percent with the short staple cottons, +43.34 percent with the medium staple cottons, and +22.83 percent with the long staple cottons. This repetition arises by virtue of the fact that four of the factors of each combination of five are common to both.

In the light of these findings, it is apparent that the values obtained for the coefficients of simple determination ($\bar{r}^2 \times 100$) were influenced appreciably by the nature and scope of the effects of the fiber-measure interrelationships which were present and wholly ignored in the simple correlation analyses. That is, the values were pyramided highly when a preponderance of positive effects were present; they were depressed severely when a relatively high degree of negative effects were operating; and they were affected only to a moderate or minor extent when the total of the interrelationships and effects present was small or when the positive and negative interrelationships tended to balance each other out in effect toward yarn-strength variance. The pattern of values obtained from the simple correlation analyses, moreover, followed the pattern of effects of the fiber-measure interrelationships previously presented in this report for different combinations of fiber measures, including alternative fiber strength measures, and representing cottons of three different staple-length levels.

GROSS EFFECTS VERSUS NET EFFECTS

The degree to which the effects of the existing fiber-measure interrelationships influenced the values for the relative gross importance of the individual and collective factors to yarn-strength variance, as presented in the previous chapter, is indicated by comparing those $\bar{r}^2 \times 100$ values in reference to relative gross effects with the corresponding beta$^2 \times 100$ values representing the relative net effects. Such a comparison of values is made in table 25 for the five factors, including fiber strength at the ⅛-inch gauge, for the three series of cottons representing different staple-length levels.

The difference values in table 25 show that the sum of the five $\bar{r}^2 \times 100$ values is less than the sum of the five beta$^2 \times 100$ values by −3.45 percent units of explainable yarn-strength variance for the short staple cottons, +38.45 percent units larger for the medium staple cottons, and +135.44 percent units larger for the long staple cottons. With the short staple cottons, all the difference values were negative, except one (fiber strength at the ⅛-inch gauge); with the medium staple cottons, all the difference values were positive, except one (micronaire); and with the long staple cottons, all the difference values were positive.

In an earlier chapter of this report, it was shown that most of the total interactions and residuals evaluated by the respective multiple correlation analyses with yarn strength, representing 5 cotton fiber measures including alternative fiber strength measures, was due to the net summation of positive and negative effects arising from the interrelationships associated with the 10 pairs of fiber measures involved $\left(\frac{5 \times 4}{2}\right)$. But, for the total five $\bar{r}^2 \times 100$ values obtained with the various series of cottons, the evaluated net effects arising from the interrelationships represent not a total of 10 pairs of fiber measures but, in fact, 20 pairs of fiber measures (5×4) or, more precisely, 10 duplicate pairs of fiber measures. This is because the interrelationship representing each of the 10 pairs of fiber measures expresses itself twice in these evaluations, the same interrelationship having been considered twice so to speak by its being identified with each of the two fiber measures included for each of the 10 pairs of fiber measures.

Thus, in order to have a comparable basis of comparison for estimating the degree to which the interrelationships associated with the 10 individual pairs of fiber measures influenced the gross values ($\bar{r}^2 \times 100$) obtained from the simple correlation analyses, the difference values reported in table 25 should be divided by the factor 2. Then, such adjusted values may be compared directly with the values for total interactions and residuals, as evaluated by the respective multiple correlation analyses with each series of cottons, the latter of which approximate the total net effects on yarn-strength variance resulting from the interrelationships associated with the 10 pairs of fiber measures under each set of conditions. The following tabulation of comparative values is self-explanatory and very revealing:

Five fiber measures, including fiber strength at ⅛-inch gauge	*Variance in yarn strength for cottons—* *Short staple (percent)*	*Medium staple (percent)*	*Long staple (percent)*
(1) $1/2(5\ \bar{r}^2 \times 100 - 5\ \text{beta}^2 \times 100)$	−1.73	+19.23	+67.72
(2) Interactions and residuals ($\bar{R}^2 \times 100 - 5\ \text{beta}^2 \times 100$)	−.61	+14.29	+40.30
Difference (1)−(2)	−1.12	+4.94	+27.42

In the light of the above tabulation for the five factors, including fiber strength at the ⅛-inch gauge, it appears that the difference values for ½ (sum of $5\bar{r}^2 \times 100$—sum of 5 beta$^2 \times 100$) follow the same general pattern with the cottons of different staple-length levels as do the respective values for total interactions and residuals evaluated by the corresponding multiple correlation analyses. On the basis of this evidence, it seems reasonable to conclude that the fiber-measure interrelationships identified with the three series of cottons influenced proportionately the corresponding values obtained from the simple correlation analyses, producing both negative and positive effects of a visible amount on the end results as reasonably might be expected; and that a large proportion of the disparity between the respective gross and net effects evaluated for the factors, including fiber strength at the ⅛-inch gauge, toward yarn-strength variance can be explained in terms of the effects of the fiber-measure interrelationships identified with the three series of cottons.

The difference values shown in the foregoing tabulation indicate, moveover, that some factors and effects other than those identified with the multiple interactions and residuals, and fiber-measure interrelationships also influenced the results from the simple correlation analyses. That is, other factors and effects increased slightly the negative differential for the short staple cottons, they increased to a small degree the positive

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differential with the medium staple cottons, and they increased appreciably the positive differential with the long staple cottons. Such findings as these, however, are not surprising in view of the fact that all associated factorial relationships, interrelationships, interactions, and residuals were ignored completely in those simple correlation analyses.

In table 26, corresponding values are summarized for the five factors, including fiber strength at the 0 gauge, for the three series of cottons of different staple-length levels. It is of special interest to note that the sum of the five $\bar{r}^2 \times 100$ values is less than the sum of the five beta$^2 \times 100$ values by -30.55 percent units of explainable yarn-strength variance for the short staple cottons, -3.32 percent units less for the medium staple cottons, and $+104.67$ percent units larger for the long staple cottons. With the short staple cottons, all the difference values were negative; with the medium staple cottons, three of the difference values were negative and two were positive; and with the long staple cottons, all of the difference values were positive.

Following is a tabulation of the adjusted and comparative values obtained from the analyses including fiber strength at the 0 gauge, as was done previously for the analyses including fiber strength at the ⅛-inch gauge:

Five fiber measures, including fiber strength at 0 gauge	*Variance in yarn strength for cottons—* *Short staple (percent)*	*Medium staple (percent)*	*Long staple (percent)*
(1) ½($5\bar{r}^2 \times 100 - 5$ beta$^2 \times 100$)	-15.28	-1.66	$+52.34$
(2) Interactions and residuals ($\bar{R}^2 \times 100 - 5$ beta$^2 \times 100$)	-19.79	$-.93$	$+33.97$
Difference (1)−(2)	$+4.51$	$-.73$	$+18.37$

Thus, on the basis of the above tabulation for the five factors, including fiber strength at the 0 gauge, the difference values for ½ (sum of 5 $\bar{r}^2 \times 100$—sum of 5 beta$^2 \times 100$) follow the same general trend with the cottons of different staple-length levels as do the respective values for total interactions and residuals evaluated by the corresponding multiple correlation analyses. Here again, therefore, it may be concluded that the effects of the fiber-measure interelationships identified with the three series of cottons influenced proportionately the corresponding values obtained from the simple correlation analyses and that a large proportion of the differences between the respective gross and net effects evaluated for the factors, including fiber strength at the 0 gauge, toward yarn-strength variance can be explained in terms of the fiber-measure interrelationships associated with the three series of cottons.

The difference values shown in the foregoing tabulation indicate, again, that some factors and effects other than those identified with the multiple interactions, residuals, and fiber-measure interrelationships also influenced the results from the simple correlation analyses. In particular, other factors and effects decreased in small amount the negative differential with the short staple cottons, they increased slightly the negative differential with the medium staple cottons, and they increased appreciably the positive differential with the long staple cottons. But, as previously stated, such findings as these are not surprising—in fact they properly may be expected—in view of the fact that all associated factorial relationships, interrelationships, interactions, and residuals were ignored completely in those simple correlation analyses.

The difference values shown in tables 25 and 26 are regrouped in table 27 to provide a direct comparison between the results for the five factors (including fiber strength at the ⅛-inch gauge) and those for the five factors (including fiber strength at the 0 gauge) representing the three series of cottons of different staple-length levels. All the difference values reported in table 27 refer to percent units of yarn-strength variance explainable by the effects of the interrelationships associated with the 10 duplicate pairs of fiber measures representing the respective series of cottons.

Dividing the difference values shown in table 27 by the factor 2 gives values for the percent units of yarn-strength variance explainable by the effects of the interrelationships associated with the 10 individual pairs of fiber measures representing the respective sets of conditions. Thus, for the series of short staple cottons, the total negative effect arising from the interrelationships associated with the four factors and fiber strength at the 0 gauge was 13.55 percent units more yarn-strength variance than with the four factors and fiber strength at the ⅛-inch gauge. For the series of long staple cottons, the total positive effect arising from the interrelationships connected with the four factors and fiber strength at the ⅛-inch gauge was 15.38 percent units more yarn-strength variance than with the four factors and fiber strength at the 0 gauge. And, for the series of medium staple cottons, the disparity between the total effects from the interrelationships representing the alternative sets of fiber measures was 20.89 percent more yarn-strength variance in favor of the four fiber measures and fiber strength at the ⅛-inch gauge than with the corresponding four fiber measures and fiber strength at the 0 gauge.

NET EFFECTS: BETA COEFFICIENTS VERSUS PARTIAL CORRELATION COEFFICIENTS

The partial correlation coefficient and the beta coefficient are the two statistical measures which are now generally used with multiple correlation analyses for evaluating the relative net importance of an independent variable to a dependent variable, such as a measure of a cotton fiber property to yarn strength. For many years, however, the partial correlation coefficient was used more or less exclusively for such purposes. But, with the accumulation of pertinent evidence over a period of many years, some questions and doubts began to be raised by the present author concerning the real meaning, comparability, and reliability of the partial correlation coefficient as a measure for evaluating the relative net importance of a cotton fiber property to a dependent variable.

Webb, Richardson, and Popka (*33*) reported in 1949 the following: "Although both partial correlation coefficients and beta coefficients were calculated for evaluating the relative net importance of the respective fiber properties in most phases of the present study, only the beta coefficients are presented in this report. This is in contrast to the previous reports of this series where preference was given to the partial correlation coefficients.

"After careful study, however, it has been concluded that the beta coefficients would be better measures to use in such studies bearing on the relationships involved in cotton fiber quality than the partial correlation coefficients. This decision is based on the fact that pronounced interrelationships exist between certain fiber properties; that the relationships vary in degree and direction for different cottons and for different series of cottons; and that these fluctuating relationships cause the values of some of the partial correlation coefficients to be somewhat unreliable as measures of importance. Although the effect of these interrelationships may not be entirely eliminated by the use of the beta coefficients, it is substantially reduced over what it is with the partial correlation coefficients."

Thus, beginning in 1949, the present author and his associates have included in their subsequent publications only beta coefficients as a measure for evaluating the relative net importance of cotton fiber properties to a dependent variable. Parallel determinations, however, have been made for partial correlation coefficients with many of those multiple correlation analyses. While the respective series of values for the beta coefficients and partial correlation coefficients generally have established the same rank of importance for a given cotton fiber measure in its relation to any one of a number of dependent variables, occasional exceptions have been observed; that is, sometimes reversals have occurred in the order of rank of contribution for a cotton fiber measure as evaluated by the two different measures, especially if the parallel values are relatively small.

As many cotton technologists and statisticians continue to use today the beta coefficient and the partial correlation coefficient more or less indiscriminately for evaluating the relative net importance of a cotton fiber measure toward a dependent variable, and with about equal confidence, it seemed desirable to examine critically the values for corresponding beta coefficients and partial correlation coefficients resulting from all the analyses included in this study and report; that is, to study those comparative values in the light of the pattern of effects for the fiber-measure interrelationships previously established in this report for the 10 pairs of fiber measures representing the alternative combinations of 5 factors identified with each of the 3 series of cottons of different staple-length levels.

A detailed and comprehensive study of the kind indicated above was considered timely because insofar as is known, no such study has been made in the past and no such results appear in the published literature to date. Use of the method of approach here applied was prompted, moreover, by observations over the years to the effect that the values for partial correlation coefficients generally are larger than the corresponding ones for beta coefficients; that sometimes the corresponding beta and partial correlation values are about equal; and that occasionally the partial correlation values are actually smaller than the corresponding beta values. Obviously, inconsistencies of this nature and disparities of this extent give rise to many cause-and-effect questions.

In table 28, a summary of the values for the coefficients of partial correlation and of partial determination $\times$ 100 are given for the five cotton fiber measures, including fiber strength at the ⅛-inch gauge, in relation to strength of 22s yarn representing each of the three series of cottons. And, in table 29, corresponding paired values are listed for the five cotton fiber measures, including fiber strength at the 0 gauge. These comparative findings are self-explanatory and those which properly might be expected.

The values for the coefficients of partial determination $\times$ 100, as listed in tables 28 and 29, are regrouped in table 30 to facilitate direct comparison between the values representing fiber strength at the ⅛-inch gauge and fiber strength at the 0 gauge, and between the dual values for each of the other four factors as derived from the multiple correlation analyses representing the alternative combinations of fiber measures. It is of special interest to note that, on the basis of the partial $\overline{R}^2 \times 100$ values, fiber strength at the

⅛-inch gauge explained: +42.61 percent units more variance in yarn strength than did fiber strength at the 0 gauge for the short staple cottons; +26.16 percent units more than fiber strength at the 0 gauge with the medium staple cottons; and −4.81 percent units less than fiber strength at the 0 gauge with the long staple cottons.

In the multiple correlation analyses containing the alternative fiber strength measures, as reported in table 30, upper half mean length explained about the same amount of yarn-strength variance in both cases with the short staple cottons. But, with the medium staple cottons, upper half mean length explained −20.48 percent units less of yarn-strength variance when fiber strength at the ⅛-inch gauge was included in the multiple analysis than when fiber strength at the 0 gauge was included. And, with the long staple cottons, upper half mean length explained −33.95 percent units less of yarn-strength variance when fiber strength at the ⅛-inch gauge was included in the multiple analysis than when fiber strength at the 0 gauge was included. Thus, for medium staple and long staple cottons, the evaluated amount of net effect of upper half mean length on yarn strength was influenced very appreciably, depending on which fiber strength measure was included in the multiple analysis.

Respective differences in the parallel partial $\overline{R}^2 \times 100$ values for micronaire, length uniformity ratio, and grade, as influenced by which fiber strength measure was included in the multiple analysis, were small and inconsequential. Such difference values, therefore, need not be considered.

The total values shown at the bottom of table 30 for the partial $\overline{R}^2 \times 100$ values representing the alternative combinations of five fiber measures possess general interest. It will be noted that, for the short staple cottons, the total net effect on explainable yarn-strength variance was +41.41 percent units more when fiber strength at the ⅛-inch gauge was included in the multiple analysis than when fiber strength at the 0 gauge was included. For the medium staple cottons, however, the respective total values were approximately equal, the difference being −0.37 percent units. But, for the long staple cottons, the total net effect on explainable yarn-strength variance was −36.61 percent units less when fiber strength at the ⅛-inch gauge was included in the multiple analysis than when fiber strength at the 0 gauge was included.

Comparison of the partial $\overline{R}^2 \times 100$ values and the beta$^2 \times 100$ values, as obtained from the alternative multiple correlation analyses with strength of 22s yarn for the three series of cottons representing different staple-length levels, is of interest in this connection. Such comparative values are listed in table 31 for the five factors, including fiber strength at the ⅛-inch gauge. It will be noted that all the values for partial correlation are larger than the corresponding beta values. Some of the comparative differences are small, some are appreciable, and some, especially for the long staple series of cottons, are relatively large.

Thus, for the short staple series of cottons, the five fiber measures, including fiber strength at the ⅛-inch gauge, explained +18.28 percent units more yarn-strength variance when evaluated by the total partial correlation values than when evaluated by the total beta values; for the medium staple cottons, +11.47 percent units more; and, for the long staple cottons, +48.73 percent units more.

Similar comparative values are listed in table 32 for the five factors, including fiber strength at the 0 gauge. It is of special interest to note that four of the five partial correlation values are smaller than the corresponding beta values for the short staple series of cottons, whereas all the partial correlation values are larger with the medium staple and long staple cottons. Most of the comparative differences are small to moderate but with the long staple cottons, three of the differences are outstandingly large.

For the short staple series of cottons, the five fiber measures, including fiber strength at the 0 gauge, explained −7.62 percent units less yarn-strength variance when evaluated by the total partial correlation values than when evaluated by the total beta values. But this evaluation explained +13.41 percent units more for the medium staple cottons, and +77.40 percent units more for the long staple cottons.

The difference values shown in tables 31 and 32 are regrouped in table 33 in a manner to facilitate direct comparison of the respective difference values (partial $\overline{R}^2 \times 100 -$ beta$^2 \times 100$), as identified with the multiple correlation analyses containing fiber strength at the ⅛-inch gauge and those including fiber strength at the 0 gauge. It will be noted that the disparity between the totals representing the two sets of difference values is +25.90 percent units of yarn-strength variance for the short cottons, −1.94 percent units for the medium staple cottons, and −28.67 percent units for the long staple cottons.

Now, exactly what factorial effects were responsible for the foregoing inconsistencies and disparities between corresponding partial correlation values and beta values, representing alternative statistical measures for evaluating the relative net importance of a cotton fiber measure to yarn strength, cannot be precisely answered on the basis of the findings presented in this report. But, the comparative results reported herein make one wonder as to the many possible interacting and contributing factors and forces which are involved, and how this intricate complex

may be unscrambled or disentangled to the point of allowing the effects of the individual and collective factors of cotton quality to be evaluated with precision and certainty.

However, in spite of all the intangibles and uncertainties involved in connection with this problem at the present time, several significant observations based on the foregoing findings are worthy of mention. First and foremost is the fact that, when fiber strength at the 0 gauge was used in the multiple correlation analysis with the short staple series of cottons, the total of the five partial $\overline{R}^2 \times 100$ values was distinctly smaller than the total of the five corrresponding beta$^2 \times 100$ values, the difference being -7.62 percent units of yarn-strength variance. As previously shown in this report, the total effects of the interrelationships identified with the 10 pairs of fiber measures representing this combination of factors and the short staple series of cottons was strongly negative toward yarn stength, the only case where such occurred in this entire study. Thus, it is believed that this condition was primarily responsible for the partial correlation values being smaller than the beta values in this instance.

On the other hand, when fiber strength at the ⅛-inch gauge was included in the multiple correlation analysis with the short staple series of cottons, the total of the negative effects of the fiber-measure interrelationships toward yarn strength was inconsequantial, as previously shown in this report. Thus, the total of the five partial $\overline{R}^2 \times 100$ values was larger than that of the five beta$^2 \times 100$ values by $+18.28$ percent, as naturally might be expected.

When fiber strength at either the 0 gauge or the ⅛-inch gauge was used in the multiple correlation analysis with the long staple series of cottons, the total effect of the fiber-measure interrelationships toward yarn strength was strongly positive in both cases. Under both of those conditions, therefore, the total of the five partial $\overline{R}^2 \times 100$ values would be expected to be appreciably larger than the corresponding total of the five beta$^2 \times 100$ values, which proved to be the case. The difference was $+77.40$ percent units of yarn-strength variance with the analysis including fiber strength at the 0 gauge and $+48.73$ percent units with the analysis including fiber strength at the ⅛-inch gauge.

For the medium staple series of cottons, when fiber strength at either the 0 gauge or the ⅛-inch gauge was used in the multiple correlation analysis, the total effect of the fiber-measure interrelationships was moderate, and the respective differences between the total of five partial $\overline{R}^2 \times 100$ values and the total of five beta$^2 \times 100$ values were small, as would be expected. The difference was $+13.41$ percent units of yarn-strength variance with the analysis including fiber strength at the 0 gauge and $+11.47$ percent units with the analysis including fiber strength at the ⅛-inch gauge.

In view of all the foregoing, questions arise as to the manner in which or the mechanism by which the fiber-measure interrelationships influenced the magnitude of the respective partial correlation values obtained under the six appreciably different sets of conditions embraced by this study and forced the partial correlation values out of line more or less, in terms of yarn-strength variance, with the corresponding beta values. Such questions cannot be answered with precision and finality at the present time but some views and reasoning can be advanced on the apparent pattern of operation and effects of those fiber-measure interrelationships toward these partial correlation values.

The partial correlation coefficient, by definition and mathematics, is a function of the multiple correlation coefficient representing the total number of independent variables in their combined average relation to a dependent variable, in conjunction with the multiple correlation coefficient for each combination of independent variables representing one less than the total number of independent variables involved. In the multiple analyses reported herein, 5 fiber measures were used in each case; thus, each multiple correlation coefficient with yarn strength represents 5 factorial relationships, 10 pairs of fiber-measure interrelationships $\left(\frac{5 \times 4}{2}\right)$, as well as some other possible interactions and residuals.

The multiple correlation value referred to above is the basic evaluation used for calculating the partial correlation value for each of the five fiber measures included in the analysis; that is, it is the common value from which the multiple correlation coefficient with yarn strength representing each combination of one less than five fiber measures, or each combination of four fiber measures, is—in effect—subtracted. Each of the latter five multiple correlation coefficients, therefore, represents four factorial relationships and six pairs of fiber-measure interrelationships $\left(\frac{4 \times 3}{2}\right)$, as well as some other possible interactions and residuals.

Thus, in the light of the foregoing, it would appear that each partial correlation coefficient, in fact, also includes the effect of four pairs of fiber-measure interrelationships in addition to the net effect for the particular fiber measure. Seemingly, this comes about by reason of the fact that the multiple correlation analyses for five fiber measures and for each combination of 4 fiber measures represent the effects of 10 and 6 pairs of fiber-measure interrelationships, respectively, or the effects of a difference of 4 pairs of fiber-measure interrelationships in each case.

With the associated effects of four pairs of fiber-measure interrelationships influencing each partial correlation value, in different combinations, it seems only natural to expect that the partial correlation values in general would be smaller than the corresponding beta values (the latter of which are free or substantially free of any effects from such fiber-measure interrelationships) in the case of the analysis including fiber strength at the 0 gauge with the short staple series of cottons. Under those conditions, the negative effects of the fiber-measure interrelationships on explainable yarn-strength variance were found to be noteworthy. This is, in fact, what is shown by the comparative values listed in table 32.

On the basis of the same reasoning, it seems proper to expect the partial correlation values to be very much larger than the corresponding beta values for the long staple series of cottons, whether the analysis contained fiber strength at either the ⅛-inch gauge or the 0 gauge, because the positive effects of the fiber-measure interrelationships were so large under both sets of conditions. Reference to the comparative values listed in tables 31 and 32 reveals that such proved to be the case.

And, for the analysis including fiber strength at the ⅛-inch gauge with the short staple series of cottons as well as for the analyses including either fiber strength measure with the medium staple cottons, the partial correlation values may be expected to be only moderately larger than the corresponding beta values, due to the relatively small positive effect of the fiber-measure interrelationships involved under the three sets of conditions. That such did occur may be seen by examination of the comparative values listed in tables 31 and 32.

Finally, as the effects of 4 pairs of fiber-measure interrelationships were involved with each partial correlation value, it seems reasonable to believe that the total of the 5 partial correlation values representing each analysis with each series of cottons included the combined effects of 20 individual pairs of fiber-measure interrelationships (4×5) or, more precisely, the effects of 10 duplicate pairs of fiber-measure interrelationships. The latter comes about by virtue of the fact that, in such a tabulation, the effect of each pair of fiber-measure interrelationships is represented twice by having been identified with each of the two components of each pair of factors.

Insofar as it is known from the published literature issued by cotton technologists, this is the first reported explanation as to why partial correlation values identified with cotton fiber measures are appreciably larger in most cases than corresponding beta values; why sometimes those paired values are about equal; and why occasionally partial correlation values are actually smaller than corresponding beta values. Such being the case, whenever an appreciable amount of effects from factorial interrelationships is known to exist, or likely to exist, in the complex system under investigation; or, whenever any uncertainty or doubt exists about the presence or absence of effects from such factorial interrelationships, use of the beta coefficient for evaluating the relative net importance of an independent variable to a dependent variable is always much to be preferred over its counterpart; namely, partial correlation coefficient.

COMPARATIVE EFFECTS OF FIBER-MEASURE INTERRELATIONSHIPS, AS ESTIMATED BY DIFFERENT METHODS

Five different processes of coupling and weighting various values obtained from multiple and simple correlation analysis have been used in this study, in an effort to determine the effects on explainable yarn-strength variance from the 10 pairs of fiber-measure interrelationships, representing 5 alternative groups of cotton fiber measures when correlated with skein strength of 22s yarn processed from cottons selected to conform to three different staple-length levels. A summary tabulation of the comparative values derived is shown in table 34. It will be noted that each of five devised methods furnished a similar trend or pattern of values for the three groups of cottons of increasing staple-length level, as identified with fiber strength at the ⅛-inch gauge and with fiber strength at the 0 gauge, when included in the parallel multiple analyses. Some of the methods, however, appear to be more effective and desirable for the purpose than others. Some comments on the merits and demerits observed with the various methods will follow.

All things considered, it appears that the value for *total* interactions and residuals, as furnished by the respective multiple correlation analyses, is the most reliable method for evaluating the overall effects on explainable yarn-strength variance arising from the interrelationships connected with the 10 pairs of fiber measures involved in each multiple analysis of this study. This measure is derived directly from values furnished by the correlation analysis, as follows: $\overline{R}^2 \times 100 -$ sum 5 $\text{beta}^2 \times 100$. Such effects other than those identified with the fiber-measure interrelation-

ships, which this measure also includes, seem to be relatively small and inconsequential on the basis of the results obtained from this study.

Commendable estimates of the effects of the fiber-measure interrelationships on explainable yarn-strength variance, however, were obtained by multiplying the r^2 value representing the degree of association between each of the 10 pairs of fiber measures by the square of the sum of the two beta values identified with the pair of fiber measures involved, giving the product the appropriate sign for its effect on yarn-strength variance, and adding the 10 values algebraically. The estimated values obtained by this method for the effects of the fiber-measure interrelationships agree remarkably well, on the whole, with the corresponding values for total interactions and residuals. The trend and pattern of the two sets of values for the cottons of increasing staple-length levels follow each other rather closely and, in comparisons of this kind, it is felt that good agreement in the trend and pattern of such values is more meaningful and important than exceptionally close agreement between specific pairs of individual values.

The estimates of the effects of the fiber-measure interrelationships derived in a manner similar to the foregoing but using the sum of the squares of the two respective beta values identified with each of the 10 pairs of fiber measures, instead of the square of the sum of the two beta values, gave values on the low side for the positive effects and on the high side for the negative effects, as compared with the other set of estimates and with the total interactions and residuals. This would seem to be understandable, however, because of the fact that the exerted effect on explainable yarn-strength variance by each of the interrelationships is a so-called accumulative or collective function, representing the collective effects of the two factors being considered in tandem, and that such is represented more significantly and appropriately by the square of the sum of the two beta values involved rather than by the sum of the squares of the respective beta values.

An example is given in reference to the point under consideration. When a group of cotton fiber measures, including micronaire readings (fiber fineness in combination with fiber maturity), were correlated with yarn strength representing a given series of cottons, and when a parallel analysis was made with the same factors except that values for causticaire fineness and causticaire maturity were substituted for the micronaire values, beta values were obtained for the relative net importance of those fiber measures toward yarn strength, as follows:

Micronaire fiber fineness (in combination with fiber maturity)	−0. 300
Causticaire fiber fineness	−. 200
Causticaire fiber maturity	−. 100

Squaring the respective beta values and multiplying each by 100, it is seen that micronaire fineness in combination with maturity accounted for 9 percent units of the yarn-strength variance explained. But, when the effects of fiber fineness and maturity were considered separately, causticaire fiber fineness explained only 4 percent units and causticaire fiber maturity accounted for only 1 percent, or a total of only 5 percent units of explainable variance in yarn strength. Thus, when the effects of fineness and maturity were considered in combination, the micronaire measure explained 9 percent units of the yarn-strength variance, a difference of 4 percent points in favor of the latter over the two causticaire measures collectively.

When ½ (sum of $5\bar{r}^2 \times 100$ − sum of 5 $\text{beta}^2 \times 100$) was used as the basis for estimating the effects of the fiber-measure interrelationships, the values for the different series of cottons fluctuated from the more stable and apparently more reliable ones previously mentioned, being considerably larger for the long staple series of cottons. But, this is not surprising because other complicating and unavoidable factors also were present which, in turn, influenced the end results.

And, when the sum of five $\bar{r}^2 \times 100 - \bar{R}^2 \times 100$ was used as the basis for estimating the effects of the fiber-measure interrelationships, the values for the different series of cottons appeared to fluctuate even more than those by the foregoing method, being excessively large for the long staple series of cottons. But, again this is not surprising because other complicating and unavoidable factors were present which influenced the final results.

The same values reported in table 34 are regrouped in tables 35 and 36 in different ways to facilitate other types of comparison which are self-explanatory.

REGRESSION EQUATIONS

As the six regression equations developed in this study for skein strength of 22s yarn with five fiber measures, including alternative measures of fiber strength, representing three series of American upland cottons selected to conform to three different staple-length levels, constitute the basic mathematical expression for the average relationships existing between the combined factors

involved in each case, it is felt that those equations would be worthy of inclusion in this report. All the correlation values, derived data, and comparisons presented in this report are functions of these respective mathematical expressions in one way or another. Other cotton technologists and analysts, therefore, may desire to apply these equations to their own fiber data for purposes of estimating or predicting 22s yarn strength.

Each regression equation is composed of a constant value, which may be either positive or negative, and five regression coefficients, which may be either positive or negative depending upon the direction of the contribution of the respective factor toward yarn strength. The value shown for each regression coefficient indicates the amount of change in 22s yarn strength which accompanies a one-unit increase in the particular fiber measure. In the case of upper half mean length, the unit of measure is 1 inch. Therefore, the value shown for the regression coefficient for upper half mean length should be divided by the factor of 32, if the amount of change in 22s yarn strength which accompanies a 1/32-inch increase in upper half mean length is desired to be known.

The regression coefficients cannot serve as adequate or dependable measures for evaluating the relative importance of the respective fiber measures toward 22s yarn strength because they represent different units of measure, different degrees of standard deviation, and different levels of values. Even the regression coefficients for a particular fiber measure, as identified with each of the three series of cottons representing different staple-length levels, are not directly comparable as they reflect different degrees of standard deviation and different levels of values.

The six regression equations, together with their respective coefficients of multiple correlation ($\overline{R}$), coefficients of multiple determination ($\overline{R}^2 \times 100$), absolute standard errors of estimate ($\overline{S}$) in pounds, and relative standard errors of estimate ($\overline{S}$) in percent, are listed as follows:

With Fiber Strength at the 1/8-inch Gauge Included in the Equation

Short staple cottons (81 obs.)

$X_8' = -26.274 + 0.669X_{173} + 41.947X_{17} + 0.154X_{19} - 0.763X_{104} + 0.160X_{88}$

$\overline{R} = 0.754$; $\overline{R}^2 \times 100 = 56.83$ pct.; Abs. $\overline{S} = \pm 3.96$ lb.; Rel. $\overline{S} = \pm 4.00$ pct.

Medium staple cottons (260 obs.)

$X_8' = -26.855 + 0.714X_{173} + 25.773X_{17} + 0.219X_{19} - 3.907X_{104} + 0.418X_{88}$

$\overline{R} = 0.761$; $\overline{R}^2 \times 100 = 57.91$ pct.; Abs. $\overline{S} = \pm 5.30$ lb.; Rel. $\overline{S} = \pm 4.70$ pct.

Long staple cottons (173 obs.)

$X_8' = -41.190 + 0.734X_{173} + 41.645X_{17} + 0.362X_{19} - 5.469X_{104} + 0.406X_{88}$

$\overline{R} = 0.906$; $\overline{R}^2 \times 100 = 82.02$ pct.; Abs. $\overline{S} = \pm 4.53$ lb.; Rel. $\overline{S} = \pm 3.44$ pct.

With Fiber Strength at the 0 Gauge Included in the Equation

Short staple cottons (81 obs.)

$X_8' = -42.794 + 0.219X_{33} + 54.286X_{17} + 0.851X_{19} - 1.936X_{104} + 0.157X_{88}$

$\overline{R} = 0.470$; $\overline{R}^2 \times 100 = 22.14$ pct.; Abs. $\overline{S} = \pm 5.32$ lb.; Rel. $\overline{S} = \pm 5.40$ pct.

Medium staple cottons (260 obs.)

$X_8' = -95.508 + 0.462X_{33} + 73.695X_{17} + 0.583X_{19} - 3.980X_{104} + 0.647X_{88}$

$\overline{R} = 0.641$; $\overline{R}^2 \times 100 = 41.12$ pct.; Abs. $\overline{S} = \pm 6.27$ lb.; Rel. $\overline{S} = \pm 5.50$ pct.

Long staple cottons (173 obs.)

$X_8' = -91.502 + 1.098X_{33} + 85.224X_{17} + 0.442X_{19} - 5.846X_{104} + 0.251X_{88}$

$\overline{R} = 0.915$; $\overline{R}^2 \times 100 = 83.63$ pct.; Abs. $\overline{S} = \pm 4.32$ lb.; Rel. $\overline{S} = \pm 3.28$ pct.

Symbols used in the equations are as follows:

Where X_8' = Estimated skein strength of 22s yarn
X_{173} = Fiber strength (Pressley), 1/8-inch gauge, as an index
X_{33} = Fiber strength (Pressley), 0 gauge, in 1,000 psi
X_{17} = Upper half mean length, in inches
X_{19} = Length uniformity ratio, as an index
X_{104} = Micronaire, fineness and maturity in combination, as scale units
X_{88} = Grade of cotton, as an index

EVALUATION OF RATIOS: FIBER STRENGTH 1/8-INCH GAUGE/0 GAUGE

The magnitude of the overall positive effects of fiber-measure interrelationships toward explainable yarn-strength variance has been found to be least with short staple cottons and to increase appreciably with cottons of increasing staple-length level. On the other hand, the magnitude of the negative effects of fiber-measure interrelationships toward explainable yarn-strength variance has been observed to be greatest with short staple cottons and to decrease appreciably with cottons of increasing staple-length level. Thus, the net proportion of positive effects of fiber-measure interrelationships toward explainable yarn-strength variance increases with cottons of increasing staple-length level.

In this connection it should be pointed out that the magnitude of effects of fiber measure interrelationships on explainable yarn-strength variance, with cottons of increasing staple-length level, varies more or less depending on the number and combination of fiber measures used in the analysis. Generally speaking, these effects are greater when fiber strength at the 1/8-inch gauge is included in the analysis than when fiber strength at the 0 gauge is included. The foregoing conclusions and generalizations are supported by the correlation findings presented earlier in this report.

Such findings with respect to effects of fiber measure interrelationships should be of much interest as well as of stimulation and challenge to cotton breeders and other improvement specialists who continuously are endeavoring to develop new and improved varieties of cotton for future commercial production, that is, cottons containing superior fiber properties and superior combinations of fiber properties in terms of textile processing and product quality; and who are groping more or less all the time for new breeding targets and criteria of assistance to their individual breeding programs and of promise for American cotton. Certainly, cotton breeders have nothing to lose and much to gain by exploring the challenges and opportunities offered by such fiber-measure interrelationships as have been reported and suggested in this presentation.

Knowledge pertaining to fiber-measure interrelationships and to their effects on yarn strength, for example, can only be obtained directly as such from multiple correlation analyses involving relatively large numbers of samples and representing different staple-length levels. But this does not satisfy the needs of breeders in their developmental and improvement work pertaining to cotton varieties, progenies, and hybrids. In that kind of effort, cotton breeders are concerned primarily with countless small individual samples that represent their plant-to-plant and row-to-row selections.

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Staple Length Series, Crop Years 1954–57

The most promising clue found to date for predicting favorable and unfavorable effects of fiber-measure interrelationships toward yarn strength, on the basis of individual samples of raw cotton, is the ratio value representing the alternative fiber strength measures (1/8-inch gauge/0 gauge). A tabulation of such fiber-strength ratio values for the short staple, medium staple, and long staple series of American upland cottons used in the correlation analyses covered by this report, as well as similar values for three other series of upland cottons selected to represent a more restricted range for each of those staple-length categories and for extra long staple cottons of the American Egyptian type, is shown in table 37.

In the upper part of table 37, for the three series of upland cottons represented in the correlation analyses reported herein, it will be noted that the mean fiber-strength ratios (1/8 inch/0) were as follows: Short staple, 1.18; medium staple, 1.19; and long staple, 1.29. Each of those mean ratio values, however, represented a considerable range of individual ratio values for the respective cottons, as indicated by the following: Short staple, from 1.45 to 0.90 or a range of 0.55; medium staple, from 1.39 to 0.96 or a range of 0.43; and long staple, from 1.47 to 1.10 or a range of 0.37.

A somewhat better graduated and wider series of mean ratio values is shown in the middle part of table 37 for the three series of upland cottons selected to represent more restricted ranges for the different staple-length categories, as indicated by the following values: Short staple, 1.18; medium staple, 1.25; and long staple, 1.33. The ranges of individual ratio values for the respective cottons included in those series are shown by the following values: Short staple, 1.45 to 0.97 or a range of 0.48; medium staple, 1.42 to 0.90 or a range of 0.52; and long staple, 1.47 to 1.13 or a range of 0.34.

The largest fiber-strength ratio values obtained with the cottons studied to date were furnished by the extra long staple cottons of the American Egyptian type. Referring to table 37 again, it will be seen that the mean ratio value for this series of 57 American Egyptian cottons, crop years 1954–57, was 1.56. The individual values extended from 1.65 to 1.41 and, thereby, covered a range of 0.24.

On the basis of individual fiber strength ratios for the respective cottons, the six series of upland cottons and one series of American Egyptian cottons, as referred to in table 37, possessed a wide range of ratio values. The maximum value of the long staple upland cottons was 1.47 and

the minimum value for the short staple series was 0.90. Thus, the overall range in fiber-strength ratios for all the upland cottons was 0.57. The maximum ratio value for the extra long American Egyptian cottons was 1.65, so the overall range for the combined upland and American Egyptian cottons was 0.75.

While no fiber strength ratio values (⅛-inch/0) have been obtained for the very long, fine, and strong fibers of the Sea Island type of cotton, there is reason to expect that the general run of available Sea Island cottons would give ratio values on a general level with those reported for the American Egyptian cottons included in this study or possibly higher. As a matter of fact, the data reported by Lunenschloss and Hummel (*8*) for some Sea Island, American Egyptian, and Egyptian cottons indicate general comparability with respect to their fiber strength ⅛-inch/0 values.

Varieties, Crop Years 1954–57

As interesting and suggestive as are the fiber strength ratio values (⅛-inch/0) for the various series of American upland cottons representing different staple-length levels and for extra long staple American Egyptian cottons versus long staple upland cottons, as reported in table 37, such values assume even more meaning and significance from the standpoint of cotton breeding and quality improvement when identified by individual variety. For serving that purpose, the fiber strength ratio values identified with the principal varieties of cotton included in the correlation analyses reported herein have been assembled in table 38.

The ranges of the fiber strength ratio values listed in table 38 for the 11 varieties of cotton were moderate and generally consistent, as such values go, the largest range in values per variety being 0.31 and the smallest range being 0.12. As such varietal ranges in fiber strength ratio values are a complex expression influenced more or less, directly and indirectly, by location effects, seasonal effects, cultivation effects, date of harvesting, fiber maturity, staple length, fiber fineness, and fiber strength, they should be expected to vary appreciably for varieties of average or less than average stability in those respects; and also to be influenced by the number of cottons and locations which are represented in a tabulation as well as by the nature and scope of the geographical area which is covered.

Of the 5 short staple varieties of cotton included in table 38, representing a total of 65 cottons or samples, the smallest mean fiber strength ratio value was shown by the Rowden variety. Its mean value was 1.06 and its minimum value was only 0.90. Only slightly larger was the Hibred variety with a mean ratio value of 1.09 and with a minimum value of 0.97. Those two varieties were grown commercially rather widely in certain areas during the crop years of 1954–57, but in recent years they have largely disappeared from commercial production in the United States.

The next two short staple varieties with ascending mean fiber strength ratio values, as shown in table 38, were the Western Stormproof with a value of 1.15 and Lockett (SP–1, SF–1, 88), with a value of 1.18. It is of interest to note that the minimum ratio value for each of those varieties was larger than 1.00, being 1.06 for Western Stormproof and 1.04 for Lockett.

The short staple variety possessing the largest fiber strength ratio values, as listed in table 38, was the Paymaster (54, 54B, and 101). Its mean ratio value was 1.32 and its minimum value was 1.21; both values are larger than corresponding values for the other varieties of short staple cotton listed. As a matter of fact, Paymaster's mean ratio value of 1.32 is larger than the respective mean ratio values for the three medium staple varieties included and it is even on a par with the outstandingly large ratio value for the only long staple variety considered; namely, Acala 1517C.

Moreover, Paymaster's maximum and minimum ratio values were larger than the corresponding values for the three medium staple varieties listed; its maximum ratio value was almost as large as the maximum ratio value for the long staple variety; and its minimum ratio value was even larger than the minimum ratio value for the long staple variety. Thus, on the basis of all the data available at the present time, the fiber-strength ratio values shown by the 18 samples representing the Paymaster short staple variety are considered unusual and exceptional; in fact, the values shown for the Paymaster variety are much larger than ordinarily would be expected for short staple cottons in general and even for most medium staple cottons.

The three medium staple varieties included in table 38 and representing a total of 46 cottons or samples were on a par with each other as regards fiber-strength ratios, their mean ratio values being as follows: Coker 100W and 124, 1.25; Deltapine 15, 1.26; and Delfos 9169, 1.26. Those ratio values are larger than the mean ratio values for all of the short staple varieties considered with the exception of the Paymaster variety, as previously explained.

Acala 1517C, the only long staple variety listed in table 38 and representing a total of 69 cottons or samples, showed the very large mean fiber strength ratio value of 1.33. Its maximum individual value was 1.47 and its minimum value was 1.16, representing a range of 0.31.

The fiber strength ratio values shown for the 57 samples of two varieties of extra long staple American Egyptian cottons reported at the end

of table 38 were notably larger than those for the long staple American upland variety studied. The Pima 32 variety, represented by only six samples, showed a mean ratio value of 1.47. Even larger ratio values were exhibited by the 51 cottons or samples representing the Pima S–1 variety, its mean value being 1.57 and its individual values extending from 1.65 to 1.44. This is a range of only 0.21 which is a relatively small value, considering the large number of samples involved in the tabulation.

Varieties, Crop Year 1961

The fiber strength ratio values previously considered, as listed in tables 37 and 38, represent cottons from the crop years of 1954–57. Since that time, however, many changes have occurred in the varietal picture identified with the current commercial production of the American cotton crop; some of these changes are known and others are unknown. In any event, it is recognized that certain new and improved varieties have come into recent production on a relatively large and increasing scale; that some varieties are losing favor in popularity and are on the decline; and that other varieties have disappeared almost entirely. Thus, it becomes of interest to examine the fiber strength ratio values for the principal varieties included in a more recent crop year for which extensive data are available as a basis for determining how they compare with the ratio values previously reported for the varieties grown in 1954–57 and for learning whether or not there have been any significant changes in the ratio values during the past 5 to 8 crop years.

Listed in table 39 are the fiber strength ratio values for the principal varieties grown in the United States during crop year 1961. Of the 12 short staple varieties considered, representing a total of 149 cottons or samples, it will be noted that the mean ratio values extended from a low of 1.15 for the Parrott variety to a high of 1.32 for the Paymaster variety. By the substantial elimination from commercial production during recent years of the Rowden and Hibred varieties, the two short staple varieties which previously had shown the smallest ratio values (1.06 and 1.09), the level of ratio values for the short staple group of cottons was higher for the crop of 1961 than for the crops of 1954–57. This higher level for the group of short staple cottons as a whole was further advanced substantially by the increased and more wide-scale production of Lankart 57 and Gregg, two varieties with relatively large mean ratio values (1.26 and 1.29). Some of the other short staple varieties, moreover, were impressive in this respect.

Thus, about half of the short staple varieties now in commercial production of the American cotton crop are on a par with the medium staple varieties in current production, insofar as fiber strength ratio values are concerned. While the Paymaster variety was represented by only three cottons or samples in the 1961 annual quality survey conducted by the Cotton Division of the USDA, it is of interest to note that this variety continued to possess the largest fiber strength ratio of all the short staple varieties studied. Again, this variety showed a mean ratio value of 1.32, as it did for the crop years of 1954–57, and again it matched closely the mean ratio shown by the long staple variety of Acala 1517C variety for 1961; namely, 1.33.

The 14 medium staple varieties listed in table 39 for the 1961 crop, representing 408 cottons or samples, had mean fiber strength ratio values on a general par with those reported for the medium staple varieties grown in previous crop years. The mean ratio value per variety extended from 1.21 for Coker 100 and Dixie King to 1.30 for Acala 4–42, Deltapine Smoothleaf, Deltapine TPSA, and Fox 10. This is a range in mean ratio values of only 0.09 unit. The group of varieties representing medium staple cottons grown in the crop year 1961 did not reveal larger mean ratio values over those for former years to the extent that the group of short-staple varieties did in 1961, as previously discussed. Noteworthy ranges in ratio values, however, were shown by four of the medium staple cottons, where there was a sufficiently large number of cottons or samples per variety to warrant such a comparison (Coker 100, Deltapine 15, Acala 4–42, Deltapine Smoothleaf); three of the ratio ranges were relatively small and one was comparatively large. Those comparative features will be discussed later in this chapter.

The 4 varieties of long staple cottons grown in the crop year 1961, representing 39 cottons or samples as listed in table 39, exhibited an overall mean ratio value on a general par with that (1.33) for the Acala 1517C variety grown in the crop years 1954–56. On the basis of 29 samples tested from the 1961 crop, Acala 1517C again showed a mean ratio value of 1.33 as it did for the 1954–57 crop years previously considered. In terms of only three or four cottons or samples per variety in 1961, which is too small a number for any reliable comparison, it is of interest, nevertheless, to note that the Acala 1517BR variety furnished the smallest mean ratio value (1.21) of the long staple cottons studied, whereas the Del Cerro variety gave the largest mean ratio value (1.44), followed by a slightly smaller mean ratio value for Acala 1517D (1.40). The range in mean ratio values for the long staple cottons tested from the 1961 crop, therefore, was 0.23 units and two of the varieties showed the largest mean ratio values that have been observed to date for such upland cottons. While the mean ratio values identified with the group of 1961 long staple cottons were somewhat larger than those found for such cottons

in the crop years 1954–56, the increases in this respect were not nearly so large and conspicuous as that for the 1961 group of short staple cottons, as previously noted.

For the 1961 extra long staple cottons reported in table 39, representing 18 samples and the two American Egyptian varieties of Pima S–1 and Pima S–2, the mean and range values for fiber strength ratio were on a general par with those observed with Pima S–1 for the crop years 1954–57. Pima S–2, however, tended to show slightly larger ratio values (1.59) than did Pima S–1 (1.55). No samples of Pima 32 were included in the annual survey for the crop 1961 but the six samples of this variety reported for the crop years 1954–57 showed a mean ratio of 1.47 with values extending from 1.53 to 1.41. Thus, the ratio values for the more recent Pima S–1 and Pima S–2 varieties are appreciably larger than the previous ones for the Pima 32 variety which has now disappeared largely from commercial production.

Varietal Ratio Ranges, Crop Year 1961

Data are not available for making any specific and precise comparison of varietal stability with respect to fiber strength ratio values, as the varieties used in the annual survey were not all grown at each and every location involved; the geographical, growth, and seasonal conditions varied more or less from variety to variety; and the number of samples or cottons per variety varied appreciably. Attention, however, will be called to the ratio ranges identified with some of the 32 varieties listed for the crop year of 1961.

First, as previously indicated, it is thought that fiber strength ratio values for cotton samples are a complex function and expression of variety, as influenced directly and indirectly—in varying degrees—by a host of cumulative and compensative effects arising from all the combined locational and seasonal factors operating individually and collectively in cotton production. In spite of all such limitations and reservations, however, the available data on fiber strength ratios allow some empirical observations and gross comparisons of a preliminary nature to be made in reference to variety, as identified with the 1961 crop and as reported in table 39. At all geographical points or areas, it should be remembered that the data represent samples or lots of cotton collected at intervals of 3 weeks throughout the harvesting season.

The short staple variety, Lankart 57, represented by 66 lots of cotton grown at 4 locations in Oklahoma and at 15 locations in Texas, or a total of 19 locations in both States, furnished a range in ratio values of 0.32 units (1.41 to 1.09). This range is appreciable but not excessive in view of the relatively wide range of geographical or place and seasonal effects involved with such a large number of samples.

The medium staple variety, Coker 100, represented by 48 lots of cotton grown at 3 locations in Alabama, at 4 locations in Georgia, at 3 locations in North Carolina, at 5 locations in South Carolina, and at 1 location in Virginia, making a total of 16 locations for the five States, showed a range in ratio values of 0.40 units (1.39 to 0.99), the largest range observed with any of the varieties studied in connection with the 1961 crop. This series of samples, however, represented an extremely wide range of geographical and growth conditions.

In particular, the three samples of the Coker 100 variety from Belleville, Ga., showed only small ratio values (1.11 to 1.07); the ratio values for the three samples from Fitzgerald, Ga., were even smaller (1.07 to 1.04); the three samples from Denmark, S.C., were small (1.14 to 1.16); and the three samples from Garnett, S.C., were smaller (1.13 to 0.99).

It was the exceedingly small values furnished by the foregoing 12 samples, representing four locations and two States, which extended the range of ratio values for the Coker 100 variety so far on the low side and which, in turn, reduced appreciably the mean ratio value expected for this variety. This is a matter that cotton breeders and specialists of the various State experiment and extension services well might look into and explore in an effort to determine the probable cause-and-effect relations involved and to prevent reoccurrences in future crop years.

The medium staple variety, Acala 4–42, represented by 58 samples grown at 18 locations in California and at 1 location in Arizona, showed a small range in ratio values of only 0.20 (1.39 to 1.19), which might indicate stability of the variety for such a large number of cottons or samples. Yet, a small range in such ratio values reasonably might be expected as the geographical area represented is limited and restricted in a sense, and as the growth conditions throughout were relatively uniform and favorable to cotton production.

The medium staple variety, Deltapine 15, represented by 56 lots of cotton grown at 1 location in Alabama, at 3 locations in Arkansas, at 3 locations in Louisiana, at 6 locations in Mississippi, at 1 location in Missouri, at 1 location in Oklahoma, at 1 location in Tennessee, and at 2 locations in Texas, making a total of 18 locations and embracing eight States, gave a range in ratio values of only 0.21 (1.41 to 1.20). This range is exceptionally small for such a large number of cotton samples, representing so many different growth locations and extending over such a wide geographical area.

Certainly, the growth and seasonal conditions must have varied appreciably over the area from which this group of 56 lots of Deltapine 15 cotton

came; these variations were intensified further by the fact that the samples were collected at intervals of 3 weeks throughout the harvesting season at each point, as follows: four collections at 3 locations, three collections at 14 locations, and two collections at 1 location. All things considered, therefore, it is concluded that the Deltapine 15 variety is, in some manner and for some unknown reason or reasons, relatively stable in terms of fiber strength ratio values.

The medium staple variety, Deltapine Smoothleaf, represented by 115 samples of cotton grown at 7 locations in Arizona, at 3 locations in California, at 6 locations in Arkansas, at 4 locations in Louisiana, at 6 locations in Mississippi, at 3 locations in Tennessee, and at 3 locations in Texas, making a total of 32 locations in seven States, and spanning the entire U.S Cotton Belt (with the exception of the South Atlantic States), furnished a range in ratio values of only 0.26 (1.43 to 1.17). This range is viewed as being outstandingly small and noteworthy for such a large number of cotton samples, representing so many different growth locations and extending over such a wide geographical area.

Here again, the growth and seasonal conditions must have varied widely over the area from which this group of 115 lots of Deltapine Smoothleaf cotton came, as extended further by the samples having been collected at 3-week intervals throughout the harvesting season at each point, as follows: six collections at 2 locations, five collections at 1 location, four collections at 12 locations, three collections at 16 locations and 2 collections at 1 location. In view of all the foregoing considerations, therefore, it is concluded that the Deltapine Smoothleaf variety also is, for some unknown reason or reasons, relatively stable with respect to fiber strength ratio values. This finding in reference to the Deltapine Smoothleaf variety is all the more interesting because its very close genetic relative, Deltapine 15, gave such similar and highly uniform values for its fiber strength ratios.

The long staple upland variety, Acala 1517C, represented by 29 lots of cotton grown at 1 location in Arizona, at 1 location in Nevada, at 4 locations in New Mexico, and at 2 locations in Texas, making a total of 8 locations in four States, gave a range in ratio values of 0.24 (1.45 to 1.21). This is considered to be in line with what might be expected from the range of growth conditions involved.

The extra long staple variety of American Egyptian cotton, Pima S–1, represented by 15 samples grown at 2 locations in Arizona, at 1 location in New Mexico, and at 2 locations in Texas, making a total of 5 locations in three States, gave a range in ratio values of 0.17 (1.66 to 1.49). This relatively narrow range in ratio values is due, in substantial part, to the fact that all American Egyptian cotton is commercially grown under comparatively uniform conditions of controlled and regulated irrigation and favorable growth.

The Ratio Challenge and Opportunity

Precisely how and why fiber strength ratio values develop as they do, and how and why they possess the significance in reference to cotton fiber quality evaluation that they seemingly do is not known at this time. For the time being, therefore, no answer given to those questions is complete and adequate, and any answer to them is more or less problemmatical, academic, and speculative.

The fact that fiber strength ratio values give some unexplained basis for predicting fiber-property interrelationships identified with individual samples and varieties of cotton is viewed as possibly constituting an important breakthrough in cotton fiber technology, findings of this kind being basic to the development of a new dimension in concepts and procedures for evaluating cotton fiber quality. In addition, such developments should be of valuable assistance to future cotton breeding and quality improvement, as well as to textile processing, quality control, and product quality.

To illustrate the possibilities in connection with cotton breeding, the Paymaster variety, a short staple cotton which ordinarily might be expected to have a fiber strength ratio (⅛-inch/0) value of about 1.10, has shown, in fact, the relatively large mean ratio value of 1.32. This ratio value is on a par with that obtained for the longest American upland variety studied; namely, Acala 1517C with a mean ratio value of 1.33. Thus, if breeders could improve the fiber-measure interrelationships of short staple, medium staple, and long staple varieties of cotton, these improvements should benefit American cotton in terms of fiber and product quality and help it to compete in world markets against synthetic and other natural fibers.

Some American varieties of cotton in current commercial production have shown a relatively narrow range of fiber strength ratio (⅛-inch/0) values for samples representing a large geographical area of growth, whereas other varieties have shown an outstandingly wide range of values under such conditions. But, how much those disparities are due to varietal stability and instability nobody knows today; in fact, cotton breeders themselves have no knowledge on this subject, as they never before have considered fiber quality in their varietal stocks, genetic crossings, and countless progenies from this point of view. Nevertheless, these observations present cotton breeders and quality-improvement specialtists with some important challenges of interest and promise

for American cotton. Certainly, these workers have nothing to lose and much to gain by exploring these challenges and opportunities to the fullest extent possible during the next several years.

Thus, for the time being and until proved otherwise, it is concluded that the factor of fiber strength ratio (1/8-inch/0) offers a promising new breeding target and a hopeful new breeding criterion for constructive and progressive use in the broad effort that continuously is being made toward promoting and achieving improvements in the quality of American cotton, one of this nation's most important agricultural commodities for industrial use.

DISCUSSION

Every cotton plant, every cotton seed, and every cotton fiber is a product of its heredity and environment, so each is a biological complex from its beginning throughout its development and existence. The problem of unmasking, unmeshing, bringing into focus, and evaluating the direct and indirect relationships operating among the many variables which influence the performance of cotton fibers in textile processing and the quality of products manufactured from them is a tangled, jumbled, and variable complex. This complexity explains why there is not, and never can be, any simple study and easy solution of the broad cotton-quality problem or of any major phase of it. This also explains why the application of routine, conventional, or even more elaborate types of analysis to the cotton fiber-processing-product problem may not give results with the meaning which they seemingly possess at face value.

Thus, the true and precise meaning of results obtained from correlation analyses in reference to cotton fiber quality depend upon many factors and circumstances identified with the problem; the purpose of the study; the cottons and growth conditions involved; the drying, cleaning and ginning methods used; and the ranges and distributions of the factorial data represented in the analysis itself. Moreover, correlation results and their meaning are influenced more or less by the number and combination of quality factors or variables included in the analysis. Therefore, all such related and interrelated factors and effects as exist in each analysis must be considered, if proper interpretations are to be made of the findings derived from correlation analyses focused on cotton fiber quality, and if sound conclusions and recommendations are to be formulated on the basis of them.

In view of the foregoing considerations, it seems not only desirable but essential that more detailed and careful attention be given in the future to all pertinent factors connected with cotton-quality evaluations than has been done in the past. In particular, this includes the partitioning of values from the multiple analysis between the net effects associated with the respective independent variables and the interactional effects operating among, and expressing themselves through, the independent variables. This type of partitioning is not new to correlation methodology but its application to the cotton-quality problem, as used and emphasized herein, is new.

It may come as a surprise to many readers of this report to learn that Tolley (*15*), Ezekiel (*5*), and Elliott (*4*) were partitioning and evaluating such factorial and interactional effects with skill and emphasis in the old Bureau of Agricultural Economics, U.S. Department of Agriculture, during the early 1920's. Their pioneering work, however, had to do with multiple correlation analyses in reference to factors affecting the price of hogs, adjusting hog production to market demand, forecasting the demand and prices of hogs, analyzing input and outgo of farm organizations, and the like.

During that same historical period of more than 40 years ago, Wright (*36*, *37*) was nearby in the Bureau of Animal Industry, USDA, engaged in making similar correlation analyses and in partitioning net effects and interactional effects from the total variance explained in various dependent variables. Wright's early work was concerned more directly and extensively with certain basic problems connected with guinea pigs, livestock, and Mendelian factors of heredity; however, Wright also applied his type of analysis and his method of interpretation to many plant subjects covering a wide range, including transpiration or the movement of water through plants.

Supported by this background of correlation evidence, the findings on the nature, extent, and effects of cotton fiber-measure interrelationships reported herein raise a challenge and suggest a new emphasis for consideration in connection with all future research, testing, analyses, and evaluations pertaining to cotton quality. It is felt, therefore, that cotton technologists, textile technologists, cotton breeders, statisticians, and others concerned with precise and significant evaluations of cotton fiber properties in their relation to textile processing and product quality would do well to give consideration to this chal-

lenge and emphasis in their future thinking, work, and conclusions.

Complexities and Perplexities of Cotton Quality

The complexity of cotton quality and the difficulty of evaluating it are discussed in broad and fundamental detail, with exceptional clarity and perspective, by Palmer in his recent article (*10* pp. 474–477). Palmer concluded: "* * * cotton is after all a strangely inscrutable commodity and gives up its secrets reluctantly;" then he goes on to explain by saying in part the following: "The difficulty of understanding cotton quality grows out of its own complexity. * * * Every one of these (countless fiber) characteristics affects in some obscure way the behavior of the cotton in spinning or the quality of the spun and woven textile, and so is a factor in the quality of the raw cotton itself. Thus, if cotton fibers in a bale were uniform like nails in a keg, that is to say if they were uniformly long or short, or thick-walled or thin-walled, appraising the quality of the cotton in a bale might be fairly simple. But this is never the case."

Palmer further states in part: "Always the mass of fiber is a conglomerate of many, if not all, of these diverse properties, commingled in a myriad of permutations and combinations. The quality of the mass is governed by the proportions which fibers of these many different characteristics are of the whole, by the influence which each proportion exerts upon the properties of the manufactured textile, and by the physical interaction of fibers of one type upon those of other types. In spite of all efforts to achieve uniformity in production, cotton actually comes to market in an incredibly wide range and diversity of qualities, which have to be accurately identified and described."

The troublesome problem of cotton-quality evaluation under consideration in this report would not occur if there were no interrelationships existing between the various fiber properties, if there were no interrelationships occurring between the fiber measures, and if there were only one fiber measure per fiber property. This cotton-quality problem, moreover, would be relatively simple and easy to study if all the possible pairs of fiber measures contained in a correlation analysis did not involve such a complex interplay of factors and effects, if they did not involve such a conglomeration of positive and negative effects in varying degrees, if they did not involve so many accumulative and compensative effects of one sort or another, and if they always were free of any limiting factor or factors within or beyond the experimental system being applied.

But, cotton fibers never grow that way in nature, fiber measures never come that way, a number of alternative measures already are available for most measurable fiber properties, and new, improved, or modified testing instruments of various kinds and types are being developed and brought forth on the commercial market at an increasing rate. In addition, the inherent fiber-property and fiber-measure interrelationships differ more or less between individual and series of cottons representing different varieties, geographical growths, and staple-length levels; and evaluations of their so-called pure and interrelated factorial effects on yarn strength or on any dependent variable may fluctuate appreciably, depending on the number and combination of fiber measures used in the multiple correlation analysis for a series of cottons, as well as upon the proportion of short staple and long staple samples included in any extensive series of cottons studied.

This status is further complicated by the fact that the fiber-property and fiber-measure interrelationships of cotton are changing more or less all the time by the operating forces of nature and through the eternal struggle going on between nature and man. This continuing struggle is primarily under the design and promotion of cotton breeders. Finally, new and improved textile machines and methods are being developed and brought forward all the time for better processing of cotton fibers into yarns and fabrics, and some of those new developments may influence subsequent evaluations of the effects of fiber-measure relationships and interrelationships in terms of explainable variance of yarn strength or of other dependent variables.

Need for Care in Selecting an Analytical Method

The degree of success obtainable in the application of any type of correlation analysis or analytical method of approach for the evaluation of cotton-fiber properties cannot be assumed. Success must be established in terms of the performance of evaluated cottons in textile processing and of their contributions to the quality of products manufactured from them, and in terms of the benefit to cotton breeding and quality improvement, to marketing of cotton through trade channels, and to the selection of individual cottons and blends of cotton for textile processing and diverse end uses.

First, it can now be safely said that the usual types of multiple correlation analysis and the general kind of interpretations commonly made on the basis of such correlation values in reference to routine cotton fiber measurements, textile processing, and product quality do not tell, and cannot tell, all of the true, important, and essential details involved in such cause-and-effect relations. That is, the apparent meaning of a value for an item may, and frequently does, differ more or less from the true meaning involved. A special effort, therefore, has been made in this study to

evaluate the more exact and the more complete meaning of various factors and effects bound up in the mysterious complex of cotton fiber quality than heretofore has been done. It has been learned from this study that partitioning the total effects on the variance explained in the dependent variable (yarn strength in this instance) by a group of independent variables or fiber measures, as evaluated by multiple correlation analysis, into what is known as pure net effects with respect to the individual factors represented and as interacting and residual effects associated with them is highly important. This partitioning is required to supply the specific and more complete information needed for many practical purposes.

The development, study, and application of such specific and comprehensive information over that which is generally drawn from most multiple correlation analyses are basic and essential to the proper understanding and handling of many practical problems connected with the following: Cotton breeding and quality improvement; textile processing and quality control; product quality; the evaluation of existing fiber-test methods and measurements in terms of various dependent variables; the designing and evaluation of new and improved fiber-test methods and measurements; and the determination of the relative merits and demerits of alternative fiber test methods and measures for a particular cotton fiber property in terms of various dependent variables.

In this connection, it should be pointed out that information of the kind and scope indicated in the foregoing is not needed for the mere purpose of developing an equation, or series of equations, for predicting textile processing or any product quality on the basis of measurements of fiber properties in varying numbers and combinations, nor for selecting the best equation for a particular purpose out of any group of equations so developed. For that kind of objective, the relative merits and demerits of an equation depend only and entirely upon its precision of estimate, as based on its standard error of estimate. Thus, for predicting purposes by means of regression equations, partitioning of the total net effects evaluated for a group of factors or fiber measures on the variance of any dependent variable, yarn strength for example, is immaterial and inconsequential; in fact, doing so in connection with that single purpose would constitute more or less needless work, lost time, and wasted effort.

Distribution of Basic Data Used in Correlation Analyses

In considering the results from any correlation analyses, particularly those of the nature and scope as presented in this report, it is important to bear in mind that such values represent average composite functions of all the factorial data and variabilities that entered into the respective analyses. Distributional features of the data for all the factors used in these correlation analyses are listed in tables 5 and 6 and referred to in an earlier chapter. The distribution of cottons, by classers' staple-length designation, for the three series of cottons representing different staple-length levels used in the correlation analyses of this study, is shown in table 1.

The graphic charts illustrating the staple-length frequency of the samples composing the three series of cottons used in this study are presented in figure 1. The distribution of samples, by staple length, followed a more or less normal or symmetrical pattern with each of the series of cottons. Obviously, there must be some appreciable ranges in staple length and other factorial data for the end results from such correlation analyses to be revealing and trustworthy; that is, if a stratification of samples is made on the basis of a range in any fiber measure that is too narrow for the associated factors and effects to possess an appreciable interplay, the results obtained from such correlation analyses may be meaningless, and the purposes of the analyses may be defeated.

In figure 1, it will be seen that there was some overlapping in staple length of the three stratified series of cottons used in this study. This was unavoidable, however, due to the varietal growth-classification basis by which the samples were selected. The proportion of extremely short and long cottons represented in each series was relatively small and not serious. For example, with the short staple series, 78 percent of the cottons occurred in the three adjacent staple-length groups of $\frac{29}{32}$, $\frac{15}{16}$, and $\frac{31}{32}$ inch; with the medium staple series, 85 percent of the cottons occurred in the three adjacent staple-length groups of 1, $1\frac{1}{32}$, and $1\frac{1}{16}$ inches; and with the long staple series, 88 percent of the cottons occurred in the four adjacent staple-length groups of $1\frac{1}{16}$, $1\frac{3}{32}$, $1\frac{1}{8}$, and $1\frac{5}{32}$ inches.

Moreover, as supported by the findings obtained from this study, the fiber-measure interrelationships representing the small proportion of extremely short and extremely long cottons included in each series of samples tended to offset each other more or less; so, in effect, the findings obtained from the respective analyses reported herein actually apply more to the central tendency of cottons that went to make up each series than otherwise would have been the case. And, finally, inclusion of the small proportion of extremely short and extremely long cottons in each series permitted a wider range of combinations of data to be in operation throughout the respective analyses than otherwise would have been the case; this feature possibly added a larger degree of representativeness, stability, and practical significance to the end results.

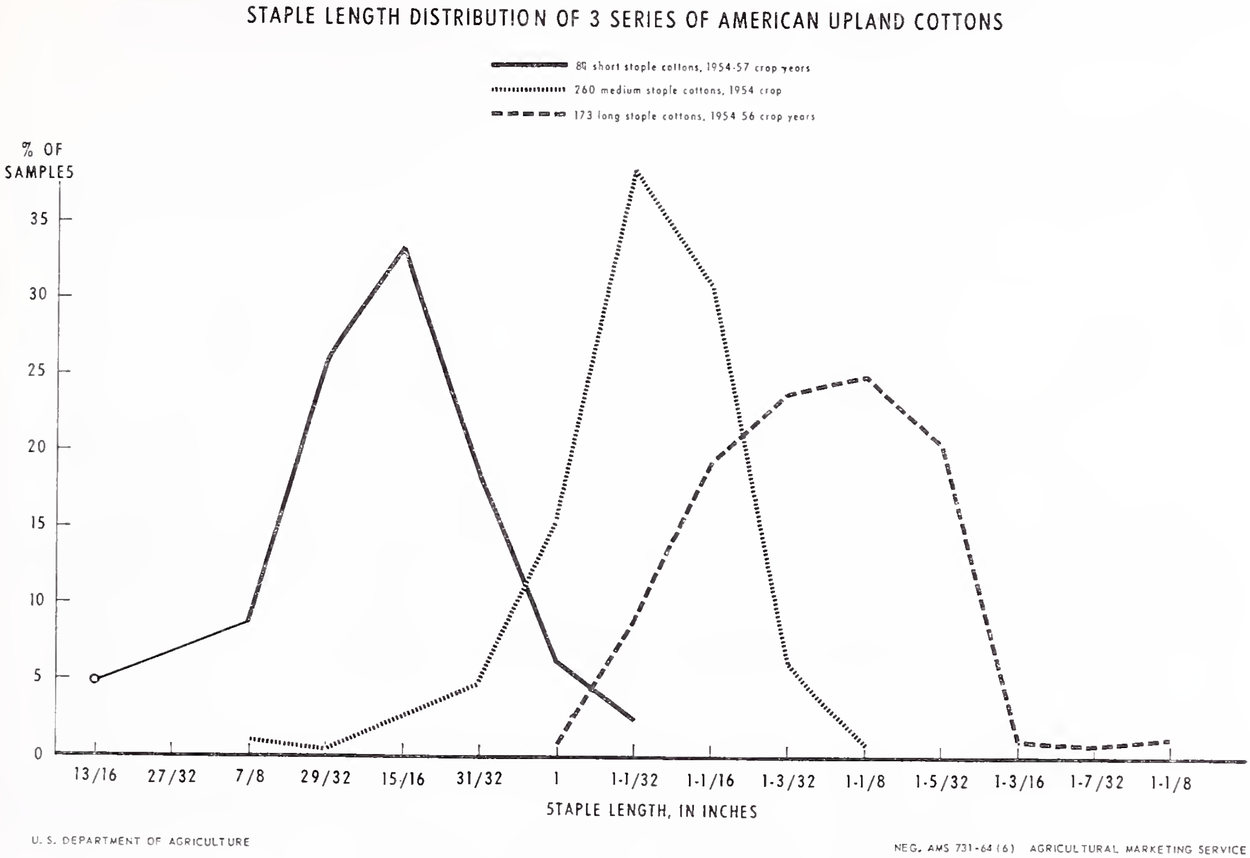

Figure 1

Integration of Results From Correlation Analyses

Coupling together, comparing, and weighting various types of results obtained from the respective correlation analyses embraced by this report are essential and indispensable to the interpretations and conclusions which have been proposed herein as a means of furthering the objectives of this study. The very numerous, widely varying, and extensive ranges of correlation values presented in tables 7 to 36 of this report, however, are too involved to be retained in mind and considered collectively. In an effort to better visualize and understand what is involved and what has been found out, therefore, the principal findings obtained from the analyses under consideration are presented in a series of four charts. Those charts support, in graphic and condensed form, the primary correlation results and supplementary evaluations presented in the previous chapters of this report. A close examination of those graphic charts should prove revealing and helpful to any reader of this report.

Figure 2 shows the total variance in strength of 22s yarn explained by the five fiber measures, including the alternative fiber strength measures and representing the three series of cottons of different staple-length levels ($\bar{R}^2 \times 100$); the amount of variance in strength of yarn explained by the respective groups of five fiber measures with each series of cottons (sum of 5 individual betas$^2 \times 100$); and the amount of variance in yarn strength explained by the interactions and residual effects ($\bar{R}^2 \times 100$—sum of 5 betas$^2 \times 100$). These data are plotted in different ways in the two sections of figure 2 to serve different purposes.

Figure 3 shows the estimated amounts of variance in 22s yarn strength explained by the effects of the 10 pairs of fiber-measure interrelationships included in each of the six multiple analyses, as compared with the corresponding total interactions and residuals evaluated by the respective multiple correlation analyses. It will be noted that the total interrelationships representing the respective groups of fiber measures is the primary contributor to the total interaction and residual effects.

Figure 4 shows the estimated amount of variance in yarn strength explained by the effects of the 10 pairs of fiber-measure interrelationships involved in each of the six multiple analyses, by the 4 pairs of fiber-measure interrelationships identified with each fiber strength measure, and by the 6 pairs of fiber-measure interrelationships

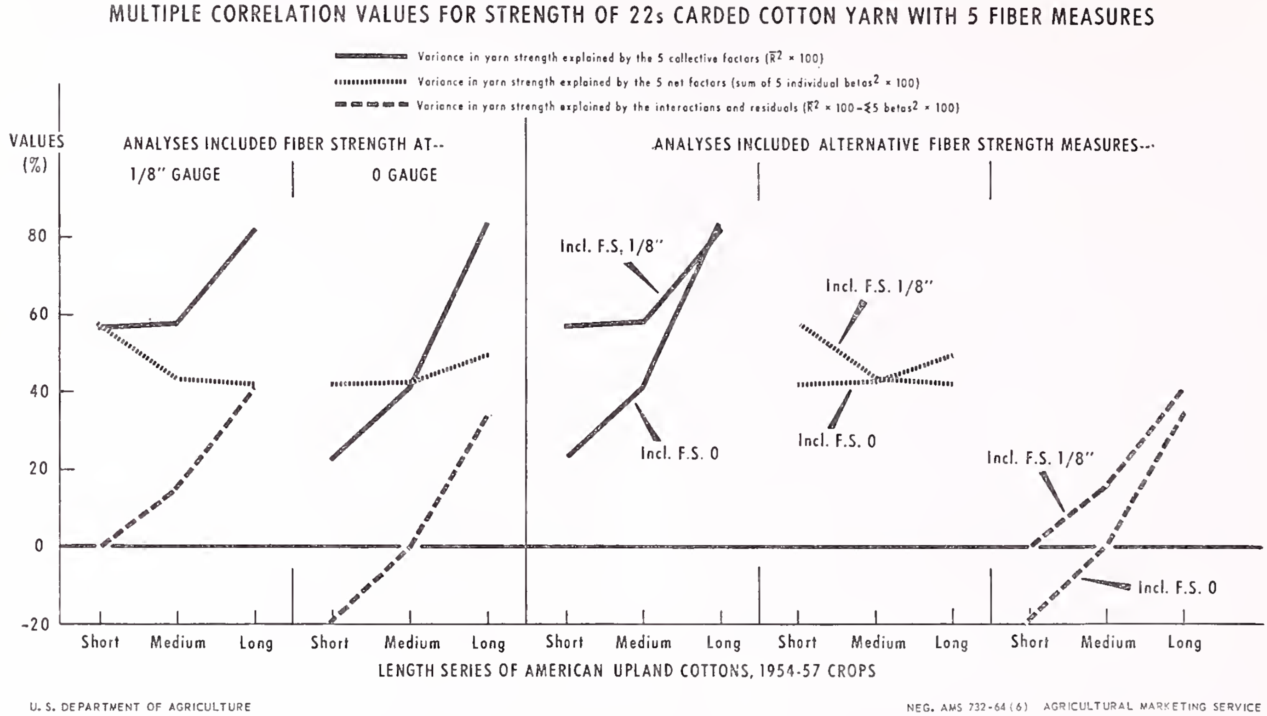

Figure 2

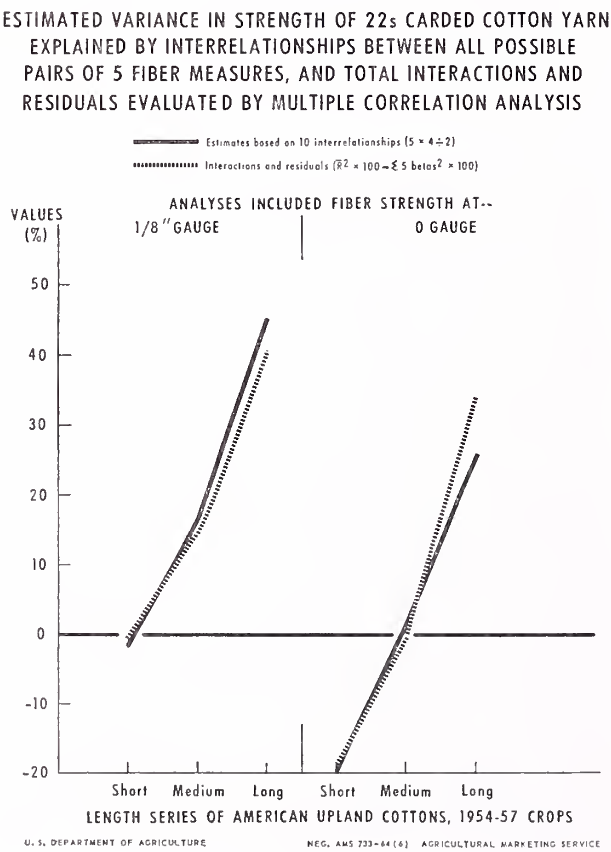

Figure 3

independent of each fiber strength measure. The same data are plotted in different directions in the two sections of figure 4 to accommodate different purposes.

Figure 5 shows the variance explained in yarn strength by the beta values (sum of 5 betas$^2 \times 100$), by the partial $\bar{r}$ values (sum of 5 partial $\bar{r}$'s$^2 \times 100$), and by the sum of the 5 simple coefficients of determination (sum of 5 simple $\bar{r}$'s$^2 \times 100$). These data are plotted in different ways in the two sections of figure 5 to serve different purposes.

Fiber Strength Ratio Values (1/8-Inch/0)

Since the completion of the principal calculations and analyses of this study, the 1961 publication and results of Lunenschloss and Hummel (*8*) of Germany have come to the attention of the writer. The authors' abstract of their article was quoted in the "Historical Review of Literature" chapter of the present report. The fiber strength ratio values (1/8-inch/0) in relation to staple-length level and variety, which were obtained in the present study and which were presented in the previous chapter of this report, follow the same general trend as similar ratio values presented by Lunenschloss and Hummel in their publication. The values obtained from the two studies, however, are not directly comparable, as the basis and level of expression were different in the two cases.

In particular, Lunenschloss and Hummel used first the two Pressley Indexes (1/8-inch/0) as the basis for calculating their fiber strength ratio

ESTIMATED VARIANCE IN STRENGTH OF 22s CARDED COTTON YARN EXPLAINED BY INTERRELATIONSHIPS BETWEEN GROUPS OF FIBER MEASURES USED IN THE MULTIPLE CORRELATION ANALYSIS

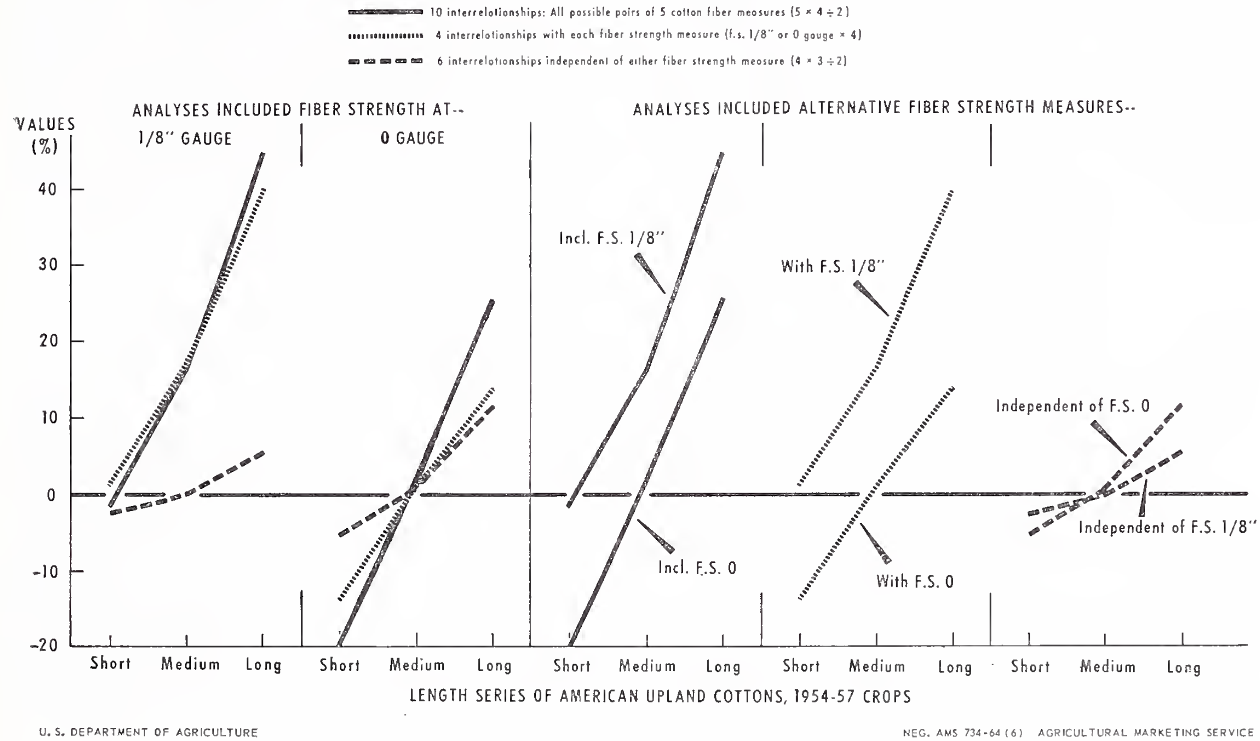

Figure 4

CORRELATION VALUES FOR STRENGTH OF 22s CARDED COTTON YARN WITH 5 FIBER MEASURES, AS OBTAINED FROM MULTIPLE AND SIMPLE CORRELATION ANALYSES

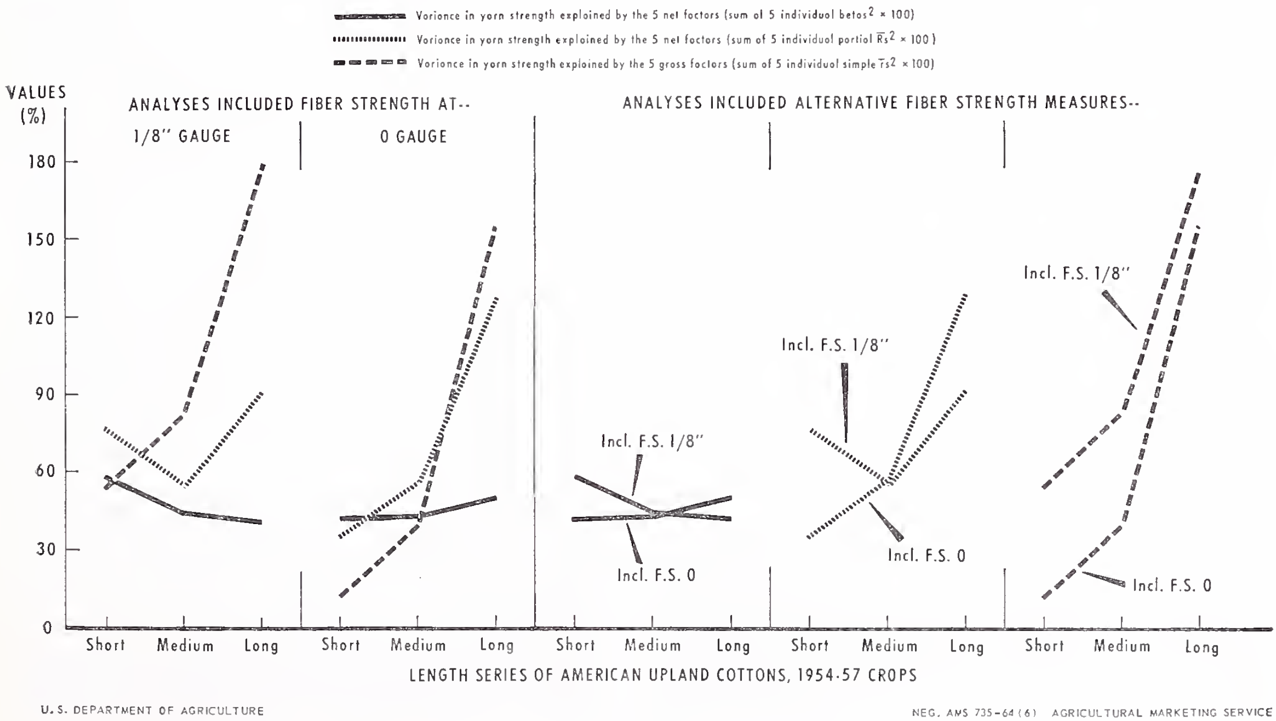

Figure 5

values. However, as the values for the Pressley Index ⅛-inch and 0 gauge lengths are not directly comparable, due to the differing weight caused by the varying lengths of the fiber samples, those investigators thereafter used fiber strength ratio values calculated on the basis of grams per tex (⅛-inch/0), the grams per tex unit used with each fiber strength measure being its fiber-bundle strength or breaking load expressed in terms of linear density. According to ASTM definitions of textile terms—D123, p. 34 (*1*), the new tex unit, which recently has been internationally adopted and now is in worldwide use, is defined as follows: "A unit for expressing linear density, equal to the weight in grams of 1 km of yarn, filament, fiber, or other textile strand."

In the study reported herein, the fiber strength ratio values (⅛-inch/0) represent fiber strength at the ⅛-inch gauge expressed as an index and fiber strength at the 0 gauge expressed in terms of 1,000 pounds per square inch. Admittedly, this is a complicated and cumbersome basis for expressing such fiber strength ratio values. But, those two methods of expression have been in common use over the years by the USDA testing laboratories which supplied the basic data used in this study and, furthermore, the correlation analyses of this study were substantially completed before the new expression of grams per tex became widely established. However, if the present study were being started anew or if it should be repeated at any time, it would be highly preferable—for many reasons—to use grams/tex as the basis for expressing the alternative fiber strength measures and their ratio values.

In spite of the fact that different bases were used for expressing the fiber strength ratio values in the two studies, a striking similarity is noted in the trend of findings furnished by each study. To illustrate, when Lunenschloss and Hummel plotted their ⅛-inch/0 ratio values (g/tex) against the upper half mean length of the respective samples, a positive trend was shown on the whole but there was a relatively wide scatter of ratios for a given upper half mean length. And, when their ⅛-inch/0 ratios were identified by variety, the smallest ratio values were obtained with the Western Stormproof and Northern Star varieties, followed by a general trend of increasing ratio values with the respective varieties of Coker, Deltapine, Acala, and Pima S–1.

Moreover, Lunenschloss and Hummel found a considerable overlapping of ⅛-inch/0 ratios by variety for the upland cottons but the ratio values for the American Egyptian Pima S–1 cotton were on a substantially higher level than those for the highest level upland variety studied; namely, Acala. Those investigators also obtained relatively large ⅛-inch/0 ratio values for Sea Island cotton, for Egyptian cotton as represented by the varieties of Karnak and Giza, and for Peruvian Pima cotton.

As an explanation for having obtained appreciably higher fiber strength ratios (⅛-inch/0) with long staple Egyptian cottons and with American Egyptian cottons than with short staple cottons, Lunenschloss and Hummel (*8*) concluded that the degree of firmness of the fiber test bundle at the ⅛-inch gauge setting showed less decline with the long staple cottons because they had less frequent or less pronounced weak points than the short staple cottons. Those investigators, however, added: "It remains to be clarified whether this property is a natural one or a result of differing methods of ginning and their attendant different types of treatment."

During recent years, the U.S. Department of Agriculture has conducted some large-scale studies on the drying, cleaning, and ginning of selected American upland cottons, including a wide range of drying and cleaning conditions, some of which were of a rather extreme nature and severe degree. No statistically significant effects, however, have been observed to date on the values of the fiber strength measure at the ⅛-inch gauge or of the fiber strength measure at the 0 gauge, representing the cottons which received such treatments at the gin. Those results have been reported and discussed by Ross and others (*13*) and by Shanklin and others (*14*).

Fiber-Measure Interrelationships

No attempt has been made in this study to explain and evaluate the factors contributing to the meaning and practical significance of the two fiber bundle strength measures (⅛-inch and 0), except insofar as certain fiber-measure interrelationships were concerned, except as those interrelationships were identified with three series of American upland cottons representing different staple-length levels, and except as the effects of those interrelationships were estimated in terms of yarn-strength variance.

Information published earlier on the Pressley fiber strength tester at the ⅛-inch gauge length and at the 0 gauge length by Wolf (*35*) and by Hadwich (*6*, *7*) has indicated certain conflicting results. Wolf, according to his report, did not find any correlation between the Pressley Index at the 0 gauge and upper half mean length. But, he reports having found a good correlation between the Pressley Index at the ⅛-inch gauge and upper half mean length, and an even higher degree of correlation between the quotient (or the ratio) of Pressley Index ⅛-inch over Pressley Index at 0 and upper half mean length.

Hadwich (*6*), studying the same two fiber strength measures, failed to find any relationship between fiber length and the ratio of the Pressley Index at ⅛-inch gauge over Pressley Index at

0 gauge, as reported previously by Wolf. The explanation for the discrepancy in results obtained by those two investigators may lie in some possible differences with respect to the distribution, range, and level of fiber strength ratio values that entered into their respective analyses.

A summary of the values for the coefficient of simple correlation ($\bar{r}$), representing the degree of relationship found to occur between each fiber strength measure and upper half mean length, as identified with each of the series of cottons used in this study, is shown in the tabulation below:

Series of cottons		*Coefficient correlation ($\bar{r}$) for upper half mean length with fiber strength at—*	
Staple	*Number*	*⅛-inch gauge*	*0 gauge*
Short-----	81	(11) 0	(4) −0.249*
Medium---	260	(1) +.465	(12) 0
Long-----	173	(1) +.633	(9) +.256

*Statistically insignificant, being less than 3 times its standard error.

Figures in parentheses indicate rank among 15 pairs of fiber measures with each series of cottons.

It will be noted from the foregoing values that, for a given series of cottons, the degree of correlation for each fiber strength measure with upper half mean length varied appreciably and that, for each fiber strength measure, the values varied appreciably with the different series of cottons. In general, those correlation values associated with the fiber strength measure at the ⅛-inch gauge were on a higher level than those associated with the fiber strength measure at the 0 gauge.

It also is of interest to observe that the correlation was zero between fiber strength at the ⅛-inch gauge and upper half mean length with the series of short staple cottons whereas it was zero between fiber strength at the 0 gauge and upper half mean length with the medium staple cottons. The relationship between fiber strength at the 0 gauge and upper half mean length, in the case of the short staple cottons, showed a negative tendency but its correlation coefficient was statistically insignificant, being less than three times its standard error.

A similar summary of values for the coefficient of simple correlation ($\bar{r}$), representing the degree of relationship found to exist between each fiber strength measure and micronaire values, as identified with each of the series of cottons used in this study, is presented in the tabulation below:

Cottons		*Coefficient correlation ($\bar{r}$) for micronaire with fiber strength at—*	
Staple	*Number*	*⅛-inch gauge*	*0 gauge*
Short-----	81	(11) 0	(1) +0.698
Medium---	260	(12) 0	(9) +.105*
Long------	173	(10) −.253	(14) −.128*

Figures in parentheses indicate rank among 15 pairs of fiber measures with each series of cottons.

*Statistically insignificant, being less than 3 times its standard error.

According to the foregoing results, the correlation values representing the relationship between the respective pairs of factors varied not only in magnitude but also in direction. The latter is of particular interest, especially the fact that fiber strength at the 0 gauge and micronaire values were correlated so strongly in the positive direction with the short staple cottons whereas fiber strength at the ⅛-inch gauge and micronaire values showed no detectable degree of correlation with the same series of cottons.

While no correlation results with yarn strength have been presented in this report involving the degree of relationship existing between the paired values of fiber strength at the ⅛-inch gauge and at the 0 gauge representing the three series of cottons of different staple-length levels, nevertheless, it is of interest at this point to observe and compare the correlation values which have been obtained for the association between those alternative measures and which are as follows:

Cottons		*Coefficient correlation ($\bar{r}$) for fiber-strength ratio at ⅛-inch gauge with fiber strength at 0 gauge*
Staple	*Number*	
Short-----	81	(5) +0.229*
Medium---	260	(2) +.350
Long------	173	(2) +.628

*Statistically insignificant, being less than 3 times its standard error.

Figures in parentheses indicate rank among 15 pairs of fiber measures with each series of cottons.

In general, the 15 simple correlation coefficients for each of the three series of cottons of different staple-length levels are too small and their standard errors of estimate are too large to conclude that any one of the measured fiber properties is closely associated with any other fiber property, or that one may estimate very accurately the magnitude of a fiber property by measuring another one. However, those fiber-property associations are of particular interest to cotton breeders who wish to know, and who must know insofar as possible, whether an improvement in one fiber property is likely to be accompanied by an improvement or deterioration in some other fiber property.

Moreover, fiber-measure interrelationships are of especial interest to cotton technologists, textile technologists, cotton breeders, and others for the varying and often appreciable extent to which they influence the results obtained from correlation analysis with some dependent variable, as yarn strength; and for the degree to which they contribute to the total interactional and residual effects evaluated by multiple correlation analysis for any group of independent variables or fiber measures included in the analysis.

Scatter diagrams of the data for each of the 15 pairs of fiber measures, representing each of the three series of cottons of different staple-length

levels, reveal a wide scatter for all the pairs and indicate a linear trend in every instance. In addition to the 6 fiber measures reported, the measures of Causticaire fineness and Causticaire maturity also have been studied as substitutions for the Micronaire measure, thus making a total of 8 fiber measures that have been considered in all and giving a grand total of 28 pairs of fiber measures studied $\left(\frac{8\times 7}{2}\right)$. Scatter diagrams for all 28 sets of those paired values showed a wide scatter and linear trend.

No trend or suggestion of a curvilinear relationship has been observed with any of the 15 or 28 pairs of fiber measures studied. In this connection, however, it should be pointed out—as previously stated in the chapter of this report entitled "Samples, Tests, and Data"—that not every grade and staple length nor the entire range of fiber properties appearing in each cotton improvement or market area throughout the annual season was represented by the test cottons whose data were included in the correlation analyses reported herein.

The limitation or restriction referred to above was unavoidable by reason of the method used in collecting the samples for fiber and spinning tests; that is, classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton improvement or market area for each period of harvesting, until 8 to 10 pounds of raw cotton had been accumulated. Therefore, for each growth area involved and for the U.S. Cotton Belt as a whole, the test samples represented in these analyses are viewed as constituting a substantial and extensive coverage of the major varieties and qualities embraced by the annual crops of American cotton for the years 1954–57.

Nevertheless, if the entire ranges of the respective cotton fiber properties had been included in the correlation analyses of this study, even though the extreme fiber-measure values would have been present only in small and minor proportions, it is not impossible that the scatter diagrams representing the values for the respective pairs of fiber measures might have shown some curvilinear tendencies or suggestions in certain instances.

Further Considerations

On the basis of the material presented in this report, it is apparent that fiber bundle strength at the ⅛-inch gauge and fiber bundle strength at the 0 gauge are relatively complex measures of cotton fiber quality and that the respective fiber strength measures yield variations and disparities in values when applied to cottons of different types and staple-length levels. That such is true and properly should be expected to be the case is further emphasized by the single fiber tensile and resilient properties recently reported by Rebenfeld and Way (*12*) for some selected cottons which they studied. Those investigators examined single fibers from length groups above and below the mean length for several types of case-historied cottons, representing *Gossypium hirsutum* and *G. barbadensae*, and they reported the dependence of some fiber mechanical properties on fiber length.

In summary, according to Rebenfeld and Way, fiber linear density decreased with fiber length while the fiber breaking tenacity and elastic modulus increased with fiber length. The fiber breaking extension and toughness increased with fiber length initially and subsequently decreased with increasing fiber length. The fiber resilience characteristics were shown to be dependent upon fiber length for only one of the cottons studied.

Statistical and Mathematical Basis for the Interpretations and Conclusions Reported

Writing on the subject of "Correlation and Causation" in USDA's Journal of Agricultural Research in 1921, or over 40 years ago, Wright (*36*) had this to say: "The ideal method of science is the study of the direct influence of one condition on another in experiments in which all other possible causes of variation are eliminated. Unfortunately, causes of variation often seem to be beyond control. In the biological sciences, especially, one often has to deal with a group of characteristics or conditions which are correlated because of a complex of interacting, uncontrollable, and often obscure causes. The degree of correlation between two variables can be calculated by well known methods, but when it is found it gives merely the resultant of all connecting paths of influence."

Wright further stated in his early publication: "The present paper is an attempt to present a method of measuring the direct influence along each separate path in such a system and thus of finding the degree to which variation of a given effect is determined by each particular cause. The method depends on the combination of knowledge of the degrees of correlation among the variables in a system with such knowledge as may be possessed by the causal relations. In cases in which the causal relations are uncertain, the method can be used to find the logical consequences of any particular hypothesis in regard to them."

In neither his 1921 publication (*36*) nor his 1934 publication (*37*) entitled "The Method of Path Coefficients" does the record show that Wright made any analyses pertaining to cotton quality. Certainly, however, his early thinking and contributions are as applicable to the present-day problem of accurately and objectively evaluating the relative contributions and importance of individual and collective cotton fiber properties to

textile processing and product quality as if, in fact, he had worked with cotton fibers. And, it may be added, cotton fibers seemingly become more classic in terms of factorial variabilities, fluctuations, complexities, and difficulties to measure and evaluate the more that their properties and characteristics are studied.

At this point, for sake of emphasis, perhaps some elaboration on the nature or meaning of the so-called pure effect of an independent variable would be desirable. First, it should be expressly understood and continuously kept in mind that an effect is "pure" *only* in the sense that it is free from interacting effects of other independent variables *considered in the equation*. And, secondly, it also should be understood and kept in mind that an unmeasured variable which is purposely left out or one which is currently unknown to the researcher may be capable of affecting a "pure" effect of one or more independent variables which are included in the equation.

For example, if a breeder of long staple cotton or a manufacturer of textile products from long staple cotton is interested in knowing whether the ⅛-inch gauge fiber strength measurement is a "pure" indicator of fiber strength, the findings obtained from the study reported herein would indicate to them that it is less "pure" than is the 0-gauge fiber strength measurement for long staple cotton. However, such a breeder or textile manufacturer also would want to have some assurance that the 0-gauge fiber strength measurement is not merely reflecting the effect of some other variable (Xi), not considered in the equation, which may or may not be physiologically or genetically related to fiber strength.

Another good example of the effects of an unmeasured variable on the "pure" effects of measured independent variables, along with an effective discussion of this problem of interpreting "pure" effects, is given on pages 202 and 203 in the 1941 edition of the textbook entitled "Methods of Correlation Analysis" by Ezekiel (*5*). All of this firmly emphasizes the fact that "pure" effects are *pure only* in relation to other variables actually measured in the equation—nothing more and nothing less.

The technique employed in the present study reported for determining "pure" effects of independent variables on the dependent variable (sum of $\text{beta}^2 \times 100$) seems to be statistically and mathematically sound when the proper interpretation is placed on "pure," as discussed in the foregoing. $\text{Beta}^2_{12.3,4,\ldots n}$ as an indication of the proportion of explained variance of X_1 attributable to X_2 net of interaction with X_3, X_4—X_n has been investigated by Tolley—see pages 554–557 in the Statistical Appendix at the end of the bulletin by Elliott (*4*), by Ezekiel (*5*, pp. 498–500), and by Wright (*36*, *37*), among others. Elliott describes Tolley's unique method in detail and gives Tolley credit for being the first person to have developed and used it.

In the foregoing publications cited, the betas are stated to be measures of the net effects of the independent variables, leaving $(\overline{R}^2 \times 100)-(\text{sum of beta}^2 \times 100)$ as the percentage of explained variation in the dependent variable attributable to interaction and residual effects. That the relationship is a true one mathematically is demonstrated by Elliott (*4*) and by Wright (*36*, *37*).

Although the relation stated above for determining the net interaction and residual effects has been shown to be a true mathematical one by the investigators mentioned in the foregoing, that what is estimated by the supplementary procedure described in this report is admittedly an approximation, and that the estimated total value never agrees exactly with the total value obtained directly from the multiple correlation analysis, the question logically arises: Why bother with any supplementary approximations as advocated herein? In order to appreciate the various advantages offered by the estimated values possible from a multiple correlation analysis over and beyond the single total value obtained directly from the same correlation analysis, it is first necessary to understand the principal details and steps involved in the supplemental procedure.

By this indirect method, which is proposed by the writer only until a better one can be developed, pairs of betas are summed and squared; multiplied by the appropriate $\bar{r}^2$ for the degree of variance found to exist between the respective pairs of fiber measures, each product value being given a plus or minus sign as based on the signs of the simple $\bar{r}$ for the relationship between the two factors in conjunction with the two signs of the corresponding betas toward the dependent variable; and summed for all the possible pairs of fiber measures operating in the multiple correlation analysis and responsible, more particularly, for that portion of the total variance explained in the dependent variable (by the group of independent variables) which is commonly referred to as "interaction and residual" effects.

From the foregoing, it is obvious that the percentage of variance explainable in the dependent variable by the interactions and interrelationships identified with each of the possible pairs of fiber measures involved in the multiple correlation analysis can be estimated by this special procedure. Moreover, for the same series of cottons, it is possible to estimate the percentage of variance explainable in yarn strength by all of the interactions and interrelationships associated with fiber strength at the ⅛-inch gauge and with fiber strength at the 0 gauge, and with those independent of those fiber strength measures.

Thus, by making similar estimates for the corresponding pairs of fiber measures—individually and by groups—representing different staple-

length levels and types of cotton, it is possible to build up a body of unusual and practical information on interactions and interrelationships relative to individual fiber measures, alternative measures of a given fiber property, and groups of fiber measures in terms of explainable variance in a dependent variable to a degree which heretofore has been impossible.

Much of the new information obtained from this study and presented in this report on the complexity of the fiber strength measure at the ⅛-inch gauge and at the 0 gauge for a particular series of cottons and for cottons of different staple-length levels was derived by, and *only* by, the application of the supplemental procedure developed in this study. Moreover, if information of this nature had not been developed in this study, no simple and visible basis in terms of fiber-measure interrelationships would yet be available for knowing why the partial $\bar{r}$'s are larger than the corresponding betas with most series of cottons; why they are about the same under some conditions; and why the partial $\bar{r}$'s are actually smaller than the betas under certain special or exceptional conditions.

In an earlier chapter of this report entitled "Net Effects: Beta Coefficients Versus Partial Correlation Coefficients," effort was made to show how and why the writer and his associates previously had concluded that the betas were to be preferred to partial r's in ranking independent variables for their importance in the type of multiple relationships involved in this study. As further proof or clarification, it may be pointed out that:

$$\text{Partial } r_{12.3\cdots n} = \text{Partial } r_{21.3\cdots n}$$

$$= \sqrt{\text{beta}_{12.3\cdots n} \times \text{beta}_{21.3\cdots n}}$$

but beta $_{12.3\cdots n}$ does not necessarily=beta $_{21.3\cdots n}$; in fact, such betas very rarely are equal.

As yarn strength is not used to predict fiber strength, there is no need of or point in calculating beta $_{21.3\cdots n}$. Moreover, as the relationship expressed in the foregoing formula shows that the partial r is an "average relation of the two betas," and as the objective is to predict yarn strength from fiber strength rather than fiber strength from yarn strength, it seems that this—in itself—would indicate that the beta $_{12.3\cdots n}$ is a better measure of the relative importance or contribution of independent variables to a dependent variable than is the partial correlation coefficient.

Summing up: In view of the statistical and mathematical considerations set forth in the foregoing, it would appear that the supplemental procedure reported herein for estimating cotton fiber-measure interactions and interrelationships in terms of explainable variance of a dependent variable possesses merit and that it well might be used as a tool for the final calibration and evaluation of the principal fiber measures currently used, of new and improved fiber instrumentations and test methods as developed in the future and before their wide-scale adoption, and—more particularly—in making special comparisons and evaluations of alternative testing equipment and methods for a particular fiber property. Such being the case, it is believed that this new analytical procedure is unique and that it properly may be regarded as one of the most important developments growing out of this study.

Caution and Precaution

Tolley, Black, and Ezekiel (*15*), as pioneers in the development of multiple correlation analysis and in the application of those techniques to many practical problems in agriculture and agricultural economics, wrote in 1924, or 40 years ago, in part, as follows:

> The statistical analysis of any given problem can be no better than the theoretical considerations upon which it is based. Statistical method is but a tool; it enables one to test or measure any specific relation or set of relations, but it cannot indicate the direction or meaning of the relations.

Peters and Van Voorhis (*11*) expressed themselves in 1940 through the preface to their text, in part, as follows:

> We believe that, if statistical workers do not take their tools as magic but understand them in the light of their origins and assumptions, they will use these tools more intelligently and more safely.

Brownlee (*2*, pp. 490–491) wrote in 1960, as follows:

> Equation (11.2) illustrates why the application of multiple-regression techniques to observational data can be so treacherous and misleading. The apparent regression of y on x_1 may really be due to the fact that y is dependent on x_3 and x_3 is correlated with x_1. We may fail to observe x_3, and attribute the regression of y on x_1 to a functional dependence which may be wholly false.
>
> In most circumstances, therefore, any indications produced by a multiple-regression analysis of observational data are merely a good hint to try for confirmation by a proper experiment. In a true experiment, the independent variables will be properly randomized with a table of random numbers and will have low correlations differing from zero by only random fluctuation, or else in a completely balanced experiment the correlations will be exactly zero.
>
> The justification sometimes advanced that a multiple-regression analysis on observational data can be relied upon if there is an adequate

theoretical background is utterly specious and disregards the unlimited capability of the human intellect for producing plausible explanations by the carload lot. For attempts to investigate these difficulties, see Tukey [3] and Simon.[4]

A further reason for being suspicious of inferences from multiple-regression analysis on observational data is that there is no guarantee that the residuals are independent.

[3] Tukey, John W., "Causation, Regression, and Path Analysis," Chapter 3, p. 35–66, in Statistics and Mathematics in Biology, Iowa State College Press, 1954. (Ames, Iowa.)

[4] Simon, Herbert A., "Spurious Correlation: A Causal Interpretation," Journal of the American Statistical Association 49, p. 467–479, 1954.

Supplemental Reading and Study

Throughout this report until reaching the "Discussion" chapter's section entitled "Statistical and Mathematical Basis for the Interpretations and Conclusions Reported," effort was made to keep the more technical terminology and discussion in reference to statistics and mathematics to a minimum for the assistance of many readers of this report who are interested in these new findings in one way or another but who, like the writer, are neither statisticians nor mathematicians. Effort also has been made to give only the more basic and essential details involved. Many readers of this report, however, may wish to pursue further various aspects of the subject and methods and the information presented in this section is submitted for that purpose and their assistance.

What is generally considered to be one of the best and most complete working descriptions of the details, procedures, fundamentals, and principles involved in the subject and usage of multiple correlation analysis is the latest edition of the volume by Ezekiel (*5*) entitled "Methods of Correlation Analysis."

The text by Peters and Van Voorhis (*11*) entitled "Statistical Procedures and their Mathematical Bases" is a very helpful source of information to have at hand for ready reference and guidance. In the authors' preface, they state: "The characteristic feature of the book is the effort to explain the mathematical origins of the most widely used statistical formulas in terms that persons with comparatively little mathematical training can easily follow. * * * In order to make such understanding available to persons of little mathematical training, we give the derivations in much detail."

The book of Brownlee (*2*) entitled "Statistical Theory and Methodology in Science and Engineering" is a most valuable and extensive compilation of information for study and assistance. The main topics covered by this book are discrete distribution, nonparametric tests, analysis of variance, regression, and correlation. Each is developed with more mathematical detail than is usual in books of this type. Yet, despite the sophistication and detail of the mathematical development, the only prerequisite is a familiarity with the simplest parts of college algebra (exponents, logarithms, simple algebraic manipulation, etc.). An understanding of elementary differential and integral calculus is helpful but not essential.

Two extensive and impressive series of literature citations by Deming (*3*) entitled "Selected Bibliography of Statistical Literature, 1930 to 1957: I. Correlation and Regression Theory. II. Time Series" appear in the Journal of Research of the National Bureau of Standards through its Mathematics and Mathematical Physics Series. (A copy of the issue cited may be obtained by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at a price of 75 cents per single copy.)

Part I of the foregoing is the first in a series of bibliographies dealing with various specific subjects in the field of statistics; 523 references and titles of important contributions in correlation and regression theory have been taken from technical journals published throughout the world since 1930. Part II is the second in this series of bibliographies; 287 references and titles of important contributions to the study of time series have been taken from a wide variety of technical journals published in the many languages and countries which have been actively engaged in statistical analysis.

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APPENDIX

Table 1.—*Distribution of 3 series of American upland cottons, by staple length, selected to represent different length levels, whose data for 6 factors of raw-cotton quality were used in parallel sets of multiple and simple correlation analyses with skein strength of 22s carded yarn, crop years 1954–57*

Class interval	Frequency of cottons by staple length for series of—		
	Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
Inches	*Percent*	*Percent*	*Percent*
13/16	4.94		
27/32	0		
7/8	8.64	0.77	
29/32	25.93	.39	
15/16	33.33	2.31	
31/32	18.52	4.62	
1	6.17	15.38	0.58
1 1/32	2.47	38.46	8.67
1 1/16		31.15	19.07
1 3/32		6.15	23.70
1 1/8		.77	24.85
1 5/32			20.23
1 3/16			1.16
1 7/32			.58
1 1/4			1.16
Total	100.00	100.00	100.00
	Inches	*Inches*	*Inches*
Mean	15/16	1 1/32	1 3/32+
Mean	.930	1.034	1.106
Maximum	1 1/32	1 1/8	1 1/4
Minimum	13/16	7/8	1
Range	7/32	1/4	1/4

Table 2.—*Distribution of selected series of short staple American upland cottons, by variety, State, and crop year, used in correlation analyses with skein strength of 22s carded yarn*

Distribution by—	Lots of cotton	
	Number	*Percent*
Variety:		
Rowden	15	18.5
Western stormproof	12	14.8
Lockett SP–1	8	9.9
Gregg	6	7.4
Hibred	6	7.4
Lockett 88	6	7.4
Parrott	6	7.4
Paymaster 54	6	7.4
Paymaster 54B	6	7.4
Paymaster 101	6	7.4
Blightmaster	3	3.7
Macha	1	1.3
Total	81	100.0

Table 2.—*Distribution of selected series of short staple American upland cottons, by variety, State, and crop year, used in correlation analyses with skein strength of 22s carded yarn*—Continued

Distribution by—	Lots of cotton	
	Number	*Percent*
State:		
Texas	66	81.5
Oklahoma	15	18.5
Total	81	100.0
Crop year:		
1954	22	27.2
1955	11	13.6
1956	15	18.5
1957	33	40.7
Total	81	100.0

TABLE 3.—*Distribution of selected series of medium staple American upland cottons, by variety and State, used in correlation analyses with skein strength of 22s carded yarn, crop year 1954*

Distribution by—	Lots of cotton	
	Number	*Percent*
Variety:		
Deltapine 15	104	40.0
Coker 100W	57	21.9
Acala 4–42	21	8.0
Arizona 44	15	5.8
Lankart 57	15	5.8
Deltapine TPSA	12	4.6
Empire	12	4.6
Deltapine Fox	6	2.3
Northern Star	6	2.3
Stoneville 2B	6	2.3
Bobshaw 1–A	3	1.2
Delfos 9169	3	1.2
Total	260	100.0
State:		
Texas	48	18.4
Mississippi	35	13.5
Arkansas	27	10.4
Georgia	24	9.2
California	21	8.1
Louisiana	21	8.1
Alabama	18	6.9
Arizona	15	5.8
North Carolina	12	4.6
South Carolina	12	4.6
Tennessee	12	4.6
Missouri	9	3.5
Oklahoma	6	2.3
Total	260	100.0

TABLE 4.—*Distribution of selected series of long staple American upland cottons, by variety, State, and crop year, used in correlation analyses with skein strength of 22s carded yarn*

Distribution by—	Lots of cotton	
	Number	*Percent*
Variety:		
Acala 1517C	81	46.9
Delfos 9169	32	18.5
Deltapine 15	15	8.7
Coker 100W	12	6.9
Acala 4–42	9	5.2
Arizona 44	9	5.2
Coker 124	6	3.5
Acala 1517BR	3	1.7
Earlistaple	3	1.7
Stoneville 2B	3	1.7
Total	173	100.0
State:		
New Mexico	45	25.9
Mississippi	38	22.0
Texas	33	19.1
Arizona	18	10.4
Arkansas	18	10.4
California	9	5.2
Missouri	6	3.5
North Carolina	6	3.5
Total	173	100.0
Crop year:		
1954	43	24.9
1955	63	36.4
1956	67	38.7
Total	173	100.0

TABLE 5.—*Mean, standard deviation, and coefficient of variation values representing the data for the factors of raw-cotton quality used in correlation analyses with skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Factors used in analyses	81 short cottons, 1954–57	260 medium cottons, 1954	173 long cottons, 1954–56
Mean for—			
Upper half mean length ... inch	0.910	1.038	1.108
Length uniformity ratio ... index	80.17	79.87	79.16
Micronaire ... scale unit	4.21	4.28	3.88
Fiber strength ⅛-in. gauge ... index	93.88	99.57	107.58
Fiber strength 0 gauge ... 1,000 p.s.i.	79.47	83.59	83.41
Grade of cotton ... index	95.38	98.70	99.39
Strength of 22s yarn ... pound	99.02	113.04	131.67
Standard deviation for—			
Upper half mean length ... inch	±0.049	±0.048	±0.057
Length uniformity ratio ... index	±1.24	±0.95	±2.41
Micronaire ... scale unit	±0.78	±0.37	±0.40
Fiber strength ⅛-in. gauge ... index	±5.50	±6.43	±7.57
Fiber strength 0 gauge ... 1,000 p.s.i.	±7.29	±4.09	±4.38
Grade of cotton ... index	±7.15	±4.54	±4.88
Strength of 22s yarn ... pound	±5.80	±8.07	±10.50
Coefficient of variation[1] for—			
Upper half mean length ... percent	±5.33	±4.65	±5.13
Length uniformity ratio ... do	±1.54	±1.19	±3.05
Micronaire ... do	±18.55	±8.74	±10.34
Fiber strength ⅛-in. gauge ... do	±5.86	±6.46	±7.04
Fiber strength 0 gauge ... do	±9.17	±4.89	±5.25
Grade of cotton ... do	±7.49	±4.60	±4.91
Strength of 22s yarn ... do	±5.86	±7.14	±7.97

[1] Standard deviation expressed as a percentage of the corresponding mean value.

TABLE 6.—*Maximum, minimum, and range values representing the data for the factors of raw-cotton quality used in correlation analyses with skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Factors used in analyses	81 short cottons, 1954–57	260 medium cottons, 1954	173 long cottons, 1954–56
Maximum for—			
Upper half mean length .... inch	1.00	1.16	1.24
Length uniformity ratio .... index	83	84	85
Micronaire .... scale unit	5.5	5.4	4.9
Fiber strength ⅛-in. gauge .... index	105	120	122
Fiber strength 0 gauge .... 1,000 p.s.i.	96	97	93
Grade of cotton .... index	105	104	105
Strength of 22s yarn .... pound	112	133	153
Minimum for—			
Upper half mean length .... inch	.79	.86	.94
Length uniformity ratio .... index	77	77	73
Micronaire .... scale unit	2.4	3.4	2.5
Fiber strength ⅛-in. gauge .... index	82	83	88
Fiber strength 0 gauge .... 1,000 p.s.i.	65	71	68
Grade of cotton .... index	75	84	85
Strength of 22s yarn .... pound	87	94	107
Range for—			
Upper half mean length .... inch	.21	.30	.30
Length uniformity ratio .... index	6	7	12
Micronaire .... scale unit	3.1	2.0	2.4
Fiber strength ⅛-in. gauge .... index	23	37	34
Fiber strength 0 gauge .... 1,000 p.s.i.	31	26	25
Grade of cotton .... index	30	20	20
Strength of 22s yarn .... pound	25	39	46

TABLE 7.—*Summary of results from multiple correlation analyses relating 5 fiber measures, including alternative fiber strength measures, to skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Statistical measure, number of observations,[1] and length series	Analysis, including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
Coefficient of correlation ($\bar{R}$):			
81 short cottons	0.754	0.470	+0.284
260 medium length cottons	.761	.641	+.120
173 long cottons	.906	.915	−.009
Variance in yarn strength explained ($\bar{R}^2 \times 100$):			
81 short cottons .... percent	56.83	22.14	+34.69
260 medium length cottons .... do	57.91	41.12	+16.79
173 long cottons .... do	82.02	83.63	−1.61
Absolute standard error of estimate ($\bar{S}$):			
81 short cottons .... pound	±3.96	±5.32	−1.36
260 medium length cottons .... do	±5.30	±6.27	−.97
173 long cottons .... do	±4.53	±4.32	+.21
Relative standard error of estimate ($\bar{S}$):[2]			
81 short cottons .... percent	±4.00	±5.40	−1.40
260 medium length cottons .... do	±4.70	±5.50	−.80
173 long cottons .... do	±3.44	±3.28	+.16

[1] Number of lots of cotton represented in each correlation analysis.

[2] Absolute standard error of estimate ($\bar{S}$) divided by corresponding mean value of yarn strength, multiplied by 100.

TABLE 8.—*Summary of beta coefficients showing the relative net importance of 5 fiber measures, including fiber strength at ⅛-inch gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative net importance		
	Rank	Beta coefficient [2]	Beta$^2 \times 100$
81 short cottons:			*Percent*
Fiber strength at ⅛-in. gauge	1	+0.633	40.07
Upper half mean length	2	+.351	12.32
Grade index	3	+.197*	3.88
Micronaire	4	−.103*	1.06
Length uniformity ratio	5	+.033*	.11
Total		1.317**	57.44
260 medium length cottons:			
Fiber strength at ⅛-in. gauge	1	+0.569	32.38
Grade index	2	+.235	5.52
Micronaire	3	−.181	3.28
Upper half mean length	4	+.154	2.37
Length uniformity ratio	5	+.026*	.07
Total		1.165**	43.62
173 long cottons:			
Fiber strength at ⅛-in. gauge	1	+0.529	27.98
Upper half mean length	2	+.226	5.11
Micronaire	3	−.209	4.37
Grade index	4	+.189	3.57
Length uniformity ratio	5	+.083*	.69
Total		1.236**	41.72

[1] Number of lots of cotton represented in each correlation analysis.

[2] The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

TABLE 9.—*Summary of beta coefficients showing the relative net importance of 5 fiber measures, including fiber strength at 0 gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative net importance: Rank	Relative net importance: Beta coefficient[2]	Relative net importance: $Beta^2 \times 100$
81 short cottons:			*Percent*
Upper half mean length	1	+0.454	20.61
Fiber strength at 0 gauge	2	+.275*	7.56
Micronaire	3	−.260*	6.76
Grade index	4	+.193*	3.72
Length uniformity ratio	5	+.181*	3.28
Total		1.363**	41.93
260 medium length cottons:			
Upper half mean length	1	+0.441	19.45
Grade index	2	+.364	13.25
Fiber strength at 0 gauge	3	+.234	5.48
Micronaire	4	−.184	3.39
Length uniformity ratio	5	+.069*	.48
Total		1.292**	42.05
173 long cottons:			
Upper half mean length	1	+0.461	21.25
Fiber strength at 0 gauge	2	+.458	20.98
Micronaire	3	−.224	5.02
Grade index	4	+.117	1.37
Length uniformity ratio	5	+.102*	1.04
Total		1.362**	49.66

[1] Number of lots of cotton represented in each correlation analysis.

[2] The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

TABLE 10.—*Relative net importance of each of 5 fiber measures toward skein strength of 22s carded yarn, as evaluated by beta coefficients from analyses including alternative fiber strength measures, for 3 series of selected American upland cottons, crop years 1954–57*

Fiber measure, number of observations,[1] and length series	Beta^2×100 from analysis including fiber strength at— ⅛-inch gauge [2] (1)	Beta^2×100 from analysis including fiber strength at— 0 gauge [2] (2)	Difference (1−2)
	Percent	*Percent*	*Percent*
Fiber strength:			
81 short cottons	(1) 40.07	(2) 7.56*	+32.51
260 medium length cottons	(1) 32.38	(3) 5.48	+26.90
173 long cottons	(1) 27.98	(2) 20.98	+7.00
Upper half mean length:			
81 short cottons	(2) 12.32	(1) 20.61	−8.29
260 medium length cottons	(4) 2.37	(1) 19.45	−17.08
173 long cottons	(2) 5.11	(1) 21.25	−16.14
Micronaire:			
81 short cottons	(4) 1.06*	(3) 6.76*	−5.70
260 medium length cottons	(3) 3.28	(4) 3.39	−.11
173 long cottons	(3) 4.37	(3) 5.02	−.65
Length uniformity ratio:			
81 short cottons	(5) .11*	(5) 3.28*	−3.17
260 medium length cottons	(5) .07*	(5) .48*	−.41
173 long cottons	(5) .69*	(5) 1.04*	−.35
Grade index:			
81 short cottons	(3) 3.88*	(4) 3.72*	+.16
260 medium length cottons	(2) 5.52	(2) 13.25	−7.73
173 long cottons	(4) 3.57	(4) 1.37	+2.20
5 fiber measures:			
81 short cottons	57.44	41.93	+15.51
260 medium length cottons	43.62	42.05	+1.57
173 long cottons	41.72	49.66	−7.94

[1] Number of lots of cotton represented in each correlation analysis.

[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5 factors, toward skein strength of 22s carded yarn.

*Corresponding beta coefficient was statistically insignificant, being less than 3 times its standard error.

TABLE 11.—*Statistical values from multiple correlation analyses representing 5 fiber measures, including alternative measures of fiber strength, with skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Statistical measure, number of observations,[1] and length series	Values from analysis, including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
Variance in yarn strength explained ($\bar{R}^2 \times 100$):[2]	*Percent*	*Percent*	*Percent*
81 short cottons	56.83	22.14	+34.69
260 medium length cottons	57.91	41.12	+16.79
173 long cottons	82.02	83.63	−1.61
Sum of 5 betas$^2 \times 100$:			
81 short cottons	57.44	41.93	+15.51
260 medium length cottons	43.62	42.05	+1.57
173 long cottons	41.72	49.66	−7.94
Interactions and residuals:[3]			
81 short cottons	−.61	−19.79	+19.18
260 medium length cottons	+14.29	−.93	+15.22
173 long cottons	+40.30	+33.97	+6.33

[1] Number of lots of cotton represented in each correlation analysis.
[2] Total variance in strength of 22s yarn explained by the 5 fiber measures included in the respective analyses.
[3] Total interactions and residuals identified with each multiple correlation analysis, representing the difference between the total variance in strength of 22s carded yarn explained by the 5 fiber measures ($R^2 \times 100$) and the sum of the 5 respective beta values squared $\times$ 100.

TABLE 12.—*Summary of coefficients of simple determination ($r^2 \times 100$) for all possible pairs (15) of 6 fiber measures, including alternative measures of fiber strength, for 3 series of selected American upland cottons, crop years 1954–57*

Pairs of fiber measures correlated: Dependent variable	Pairs of fiber measures correlated: Independent variable	Coefficient of simple determination ($r^2 \times 100$)[1] for series of— Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
		Percent	*Percent*	*Percent*
Fiber strength 0 gauge	Micronaire	(1) +(−)48.66	(9) +(−) 1.10*	(14) −(+) 1.64*
Grade index	do	(2) +(−)22.68	(5) +(−) 2.74*	(15) 0
Do	Fiber strength 0 gauge	(3) +(+)14.85	(6) +(+) 2.38*	(5) +(+)17.34
Fiber strength 0 gauge	Upper half mean length	(4) −(−) 6.21*	(12) 0	(9) +(+) 6.55
Do	Fiber strength 1/8-in. gauge	(5) +(+) 5.25*	(2) +(+)12.26	(2) +(+)39.43
Uniformity ratio	Upper half mean length	(6) −(−) 3.61*	(12) 0	(7) +(+) 8.10
Micronaire	do	(7) −(+) 3.03*	(8) −(+) 1.82*	(8) −(+) 6.84
Grade index	do	(8) −(−) 3.00*	(11) −(−) .11*	(4) +(+)17.80
Uniformity ratio	Fiber strength 1/8-in. gauge	(9) +(+) 2.27*	(10) +(+) .71*	(6) +(+)10.96
Do	Micronaire	(10) +(−) .19*	(7) +(−) 2.04*	(13) +(−) 3.47*
Fiber strength 1/8-in. gauge	Upper half mean length	(11) 0	(1) +(+)21.59	(1) +(+)40.09
Do	Micronaire	(11) 0	(12) 0	(10) −(+) 6.41
Grade index	Fiber strength 1/8-in. gauge	(11) 0	(3) +(+) 7.15	(3) +(+)17.96
Uniformity ratio	Fiber strength 0 gauge	(11) 0	(12) 0	(11) +(+) 5.45
Grade index	Uniformity ratio	(11) 0	(4) +(+) 3.92	(12) +(+) 4.32*
Total interrelationships without regard to signs		109.75	55.82	186.36
(1) Total interrelationships positive, yarn strength		25.40	49.83	182.89
(2) Total interrelationships negative, yarn strength		84.35	5.99	3.47
Difference (1)−(2)		−58.95	+43.84	+179.42

[1] The number in parentheses indicates the rank of the respective coefficients of determination, in descending order, for each series of cottons.

The first sign indicates the direction of the correlation between the respective pairs of fiber measures.

The second sign (in parentheses) indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the two beta coefficients for the respective factors.

*Statistically insignificant, the corresponding coefficient of correlation being less than 3 times its standard error.

TABLE 13.—*Summary of coefficients of simple determination ($\bar{r}^2 \times 100$) for all possible pairs (10) of 5 fiber measures, including fiber strength at the 1/8-inch gauge, for 3 series of selected American upland cottons, crop years 1954–57*

Pairs of fiber measures correlated: Dependent variable	Pairs of fiber measures correlated: Independent variable	Coefficient of simple determination ($\bar{r}^2 \times 100$) [1] for series of— Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
		Percent	*Percent*	*Percent*
Grade index	Micronaire	(2) +(−)22.68	(5) +(−) 2.74*	(15) 0
Uniformity ratio	Upper half mean length	(6) −(−) 3.61*	(12) 0	(7) +(+) 8.10
Micronaire	do	(7) −(+) 3.03*	(8) −(+) 1.82*	(8) −(+) 6.84
Grade index	do	(8) −(−) 3.00*	(11) −(−) .11*	(4) +(+)17.80
Uniformity ratio	Fiber strength 1/8-inch gauge	(9) +(+) 2.27*	(10) +(+) .71*	(6) +(+)10.96
Do	Micronaire	(10) +(−) .19*	(7) +(−) 2.04*	(13) +(−) 3.47*
Fiber strength 1/8-in. gauge	Upper half mean length	(11) 0	(1) +(+)21.59	(1) +(+)40.09
Do	Micronaire	(11) 0	(12) 0	(10) −(+) 6.41
Grade index	Fiber strength 1/8-in. gauge	(11) 0	(3) +(+) 7.15	(3) +(+)17.96
Do	Uniformity ratio	(11) 0	(4) +(+) 3.92	(12) +(+) 4.32*
Total interrelationships without regard to signs		34.78	40.08	115.95
(1) Total interrelationships positive, yarn strength		5.30	35.19	112.48
(2) Total interrelationships negative, yarn strength		29.48	4.89	3.47
Difference (1) − (2)		−24.18	+30.30	+109.01

[1] The number in parentheses indicates the rank of the respective coefficients of determination, in descending order, among the 15 obtained for 6 factors identified with each series of cottons.

The first sign indicates the direction of the correlation between the respective pairs of fiber measures.

The second sign (in parentheses) indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the 2 beta coefficients for the respective factors.

*Statistically insignificant, the corresponding coefficient of correlation being less than 3 times its standard error.

TABLE 14.—*Summary of coefficients of simple determination ($\bar{r}^2 \times 100$) for all possible pairs (10) of 5 fiber measures, including fiber strength at the 0 gauge, for 3 series of selected American upland cottons, crop years 1954–57*

Pairs of fiber measures correlated		Coefficient of simple determination ($\bar{r}^2 \times 100$) [1] for series of—		
Dependent variable	Independent variable	Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
		Percent	*Percent*	*Percent*
Fiber strength 0 gauge	Micronaire	(1) +(−)48.66	(9) +(−)1.10*	(14) −(+) 1.64*
Grade index	do	(2) +(−)22.68	(5) +(−)2.74*	(15) 0
Do	Fiber strength 0 gauge	(3) +(+)14.85	(6) +(+)2.38*	(5) +(+)17.34
Fiber strength 0 gauge	Upper half mean length	(4) −(−) 6.21*	(12) 0	(9) +(+) 6.55
Uniformity ratio	do	(6) −(−) 3.61*	(12) 0	(7) +(+) 8.10
Micronaire	do	(7) −(+) 3.03*	(8) −(+)1.82*	(8) −(+) 6.84
Grade index	do	(8) −(−) 3.00*	(11) −(−) .11*	(4) +(+)17.80
Uniformity ratio	Micronaire	(10) +(−) .19*	(7) +(−)2.04*	(13) +(−) 3.47*
Do	Fiber strength 0 gauge	(11) 0	(12) 0	(11) +(+) 5.45
Grade index	Uniformity ratio	(11) 0	(4) +(+)3.92	(12) +(+) 4.32*
Total interrelationships without regard to signs		102.23	14.11	71.51
(1) Total interrelationships positive, yarn strength		17.88	8.12	68.04
(2) Total interrelationships negative, yarn strength		84.35	5.99	3.47
Difference (1)−(2)		−66.47	+2.13	+64.57

[1] The number in parentheses indicates the rank of the respective coefficients of determination, in descending order, among the 15 obtained for 6 factors identified with each series of cottons.

The first sign indicates the direction of the correlation between the respective pairs of fiber measures.

The second sign (in parentheses) indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the two beta coefficients for the respective factors.

*Statistically insignificant, the corresponding coefficient of correlation being less than 3 times its standard error.

TABLE 15.—*Summary of coefficients of simple determination ($\bar{r}^2 \times 100$) for 4 pairs of fiber measures identified with fiber strength at the 1/8-inch gauge and with fiber strength at the 0 gauge, for 3 series of selected American upland cottons, crop years 1954–57*

Pairs of fiber measures correlated	Coefficient of simple determination ($\bar{r}^2 \times 100$) [1] for series of— Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
	Percent	*Percent*	*Percent*
Fiber strength 1/8-in. gauge with—			
Length uniformity ratio	(9) +(+) 2.27*	(10) +(+) .71*	(6) +(+)10.96
Upper half mean length	(11) 0	(1) +(+)21.59	(1) +(+)40.09
Micronaire	(11) 0	(12) 0	(10) −(+) 6.41
Grade index	(11) 0	(3) +(+) 7.15	(3) +(+)17.96
Total interrelationships without regard to signs	2.27	29.45	75.42
(1) Total interrelationships positive, yarn strength	2.27	29.45	75.42
(2) Total interrelationships negative, yarn strength	0	0	0
Difference (1)−(2)	+2.27	+29.45	+75.42
Fiber strength 0 gauge with—			
Micronaire	(1) +(−)48.66	(9) +(−) 1.10*	(14) −(+) 1.64*
Grade index	(3) +(+)14.85	(6) +(+) 2.38*	(5) +(+)17.34
Upper half mean length	(4) −(−) 6.21*	(12) 0	(9) +(+) 6.55
Length uniformity ratio	(11) 0	(12) 0	(11) +(+) 5.45
Total interrelationships without regard to signs	69.72	3.48	30.98
(1) Total interrelationships positive, yarn strength	14.85	2.38	30.98
(2) Total interrelationships negative, yarn strength	54.87	1.10	0
Difference (1)−(2)	−40.02	+1.28	+30.98

[1] The number in parentheses indicates the rank of the respective coefficients of determination, in descending order, among the 15 obtained for 6 factors identified with each series of cottons.

The first sign indicates the direction of the correlation between the respective pairs of fiber measures.

The second sign (in parentheses) indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the 2 beta coefficients for the respective factors.

*Statistically insignificant, the corresponding coefficient of correlation being less than 3 times its standard error.

TABLE 16.—*Summary of coefficients of simple determination ($\bar{r}^2 \times 100$) for 6 pairs of fiber measures independent of both fiber strength measures, for 3 series of selected American upland cottons, crop years 1954–57*

Pairs of fiber measures correlated		Coefficient of simple determination ($r^2 \times 100$) [1] for series of—		
Dependent variable	Independent variable	Short (81 cottons) 1954–57	Medium length (260 cottons) 1954	Long (173 cottons) 1954–56
		Percent	*Percent*	*Percent*
Grade index	Micronaire	(2) +(−)22.68	(5) +(−) 2.74*	(15) 0
Uniformity ratio	Upper half mean length	(6) −(−) 3.61*	(12) 0	(7) +(+) 8.10
Micronaire	do	(7) −(+) 3.03*	(8) −(+) 1.82*	(8) −(+) 6.84
Grade index	do	(8) −(−) 3.00*	(11) −(−) .11*	(4) +(+)17.80
Uniformity ratio	Micronaire	(10) +(−) .19*	(7) +(−) 2.04*	(13) +(−) 3.47*
Grade index	Uniformity ratio	(11) 0	(4) +(+) 3.92	(12) +(+) 4.32*
Total interrelationships without regard to signs		32.51	10.63	40.53
(1) Total interrelationships positive, yarn strength		3.03	5.74	37.06
(2) Total interrelationships negative, yarn strength		29.48	4.89	3.47
Difference (1)−(2)		−26.45	+0.85	+33.59

[1] The number in parentheses indicates the rank of the respective coefficients of determination, in descending order, among 15 obtained for 6 factors identified with each series of cottons.
The first sign indicates the direction of the correlation between the respective pairs of fiber measures.
The second sign (in parentheses) indicates the direction of the effect of the interrelationship between the respective pairs of fiber measures toward yarn strength, as based on the direction of the correlation between each pair of fiber measures in conjunction with the signs of the 2 beta coefficients for the respective factors.

*Statistically insignificant, the corresponding coefficient of correlation being less than 3 times its standard error.

TABLE 17.—*Estimated percentages of variance in skein strength of 22s carded yarn explained by 10 pairs of interrelationships representing 5 fiber measures, including fiber strength at 1/8-inch gauge, and total interactions and residuals evaluated by multiple correlation analysis, for 3 series of selected American upland cottons, crop years 1954–57*

Statistical item	81 Short cottons, 1954–57	260 Medium cottons, 1954	173 Long cottons, 1954–56
Fiber interrelationships toward yarn strength ($\bar{r}^2 \times 100$) for—	*Percent*	*Percent*	*Percent*
4 respective measures with fiber strength 1/8-in. gauge	+2.27	+29.45	+75.42
6 pairs of measures independent of fiber strength	−26.45	+.85	+33.59
Total, 10 pairs of fiber measures	−24.18	+30.30	+109.01
Estimated variance in yarn strength [1] due to interrelationships for—			
4 respective measures with fiber strength 1/8-in. gauge	+1.01	+16.16	+39.70
6 pairs of measures independent of fiber strength	−2.85	−.11	+5.15
Total, 10 pairs of fiber measures	−1.84	+16.05	+44.85
(1) Estimated variance in yarn strength, 10 pairs of interrelationships	−1.84	+16.05	+44.85
(2) Interactions and residuals, multiple correlation analysis [2]	−.61	+14.29	+40.30
Difference (1)−(2)	−1.23	+1.76	+4.55

[1] Estimated percentage of variance in strength of 22s yarn explainable by the interrrelationship existing between each pair of fiber measures was calculated on the basis of the square of the sum of the 2 beta values identified with each pair of factors, multiplied by 100, and multiplied by the coefficient of determination ($\bar{r}^2$) representing the interrelationship for the pair of fiber measures involved, with sign determined as explained in the text.

[2] The value for the interactions and residuals, as evaluated by each multiple correlation analysis, represents the difference between the total variance in strength of 22s yarn explained by the 5 cotton fiber measures ($\bar{R}^2 \times 100$) minus the sum of the respective beta values squared×100.

TABLE 18.—*Estimated percentages of variance in skein strength of 22s carded yarn explained by 10 pairs of interrelationships representing 5 fiber measures, including fiber strength at 0 gauge, and total interactions and residuals evaluated by multiple correlation analysis, for 3 series of selected American upland cottons, crop years 1954–57*

Statistical item	81 Short cottons, 1954–57	260 Medium cottons, 1954	173 Long cottons, 1954–56
Fiber interrelationships toward yarn strength ($\bar{r}^2 \times 100$) for—	*Percent*	*Percent*	*Percent*
4 respective measures with fiber strength 0 gauge	−40.02	+1.28	+30.98
6 pairs of measures independent of fiber strength	−26.45	+.85	+33.59
Total, 10 pairs of fiber measures	−66.47	+2.13	+64.57
Estimated variance in yarn strength [1] due to interrelationships for—			
4 respective measures with fiber strength 0 gauge	−13.98	+0.66	+13.73
6 pairs of measures independent of fiber strength	−5.87	+.43	+11.57
Total, 10 pairs of fiber measures	−19.85	+1.09	+25.30
(1) Estimated variance in yarn strength, 10 pairs of interrelationships	−19.85	+1.09	+25.30
(2) Interactions and residuals, multiple correlation analysis [2]	−19.79	−.93	+33.97
Difference (1)−(2)	−0.06	+2.02	−8.67

[1] Estimated percentage of variance in strength of 22s yarn explainable by the interrrelationship existing between each pair of fiber measures was calculated on the basis of the square of the sum of the 2 beta values identified with each pair of factors, multiplied by 100, and multiplied by the coefficient of determination ($\bar{r}^2$) representing the interrelationship for the pair of fiber measures involved, with sign determined as explained in the text.

[2] The value for the interactions and residuals, as evaluated by each multiple correlation analysis, represents the difference between the total variance in strength of 22s yarn explained by the 5 cotton fiber measures ($\bar{R}^2 \times 100$) minus the sum of the respective beta values squared×100.

TABLE 19.—*Estimated percentages of variance in skein strength of 22s carded yarn explained by 10 pairs of interrelationships representing 5 fiber measures, including alternative measures of fiber strength, and total interactions and residuals evaluated by multiple correlation analysis, for the series of 81 short staple American upland cottons, crop years 1954–57*

Statistical item	Values from analysis, including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
	Percent	*Percent*	*Percent*
Fiber interrelationships toward yarn strength ($\bar{r}^2 \times 100$) for—			
4 respective measures with fiber strength	+2.27	−40.02	+42.29
6 pairs of measures independent of fiber strength	−26.45	−26.45	.00
Total, 10 pairs of fiber measures	−24.18	−66.47	+42.29
Estimated variance in yarn strength[1] due to interrelationships for—			
4 respective measures with fiber strength	+1.01	−13.98	+14.99
6 pairs of measures independent of fiber strength	−2.85	−5.87	+3.02
Total 10 pairs of fiber measures	−1.84	−19.85	+18.01
(1) Estimated variance in yarn strength, 10 pairs of interrelationships	−1.84	−19.85	+18.01
(2) Interactions and residuals, multiple correlation analysis[2]	−.61	−19.79	+19.18
Difference (1)−(2)	−1.23	−0.06	−1.17

[1] Estimated percentage of variance in strength of 22s yarn explainable by the interrelationship existing between each pair of fiber measures was calculated on the basis of the square of the sum of the 2 beta values identified with each pair of factors, multiplied by 100, and multiplied by the coefficient of determination ($\bar{r}^2$) representing the interrelationship for the pair of fiber measures involved, with sign determined as explained in the text.

[2] The value for the interactions and residuals, as evaluated by each multiple correlation analysis, represents the difference between the total variance in strength of 22s yarn explained by the 5 cotton fiber measures ($\overline{R}^2 \times 100$) minus the sum of the respective beta values squared $\times 100$.

TABLE 20.—*Estimated percentages of variance in skein strength of 22s carded yarn explained by 10 pairs of interrelationships representing 5 fiber measures, including alternative measures of fiber strength, and total interactions and residuals evaluated by multiple correlation analysis, for the series of 260 medium staple American upland cottons, crop year 1954*

Statistical item	Values from analysis, including fiber strength at—		
	⅛-in. gauge (1)	0 gauge (2)	Difference (1−2)
	Percent	*Percent*	*Percent*
Fiber interrelationships toward yarn strength ($\bar{r}^2 \times 100$) for—			
4 respective measures with fiber strength	+29.45	+1.28	+28.17
6 pairs of measures independent of fiber strength	+.85	+.85	.00
Total, 10 pairs of fiber measures	+30.30	+2.13	+28.17
Estimated variance in yarn strength [1] due to interrelationships for—			
4 respective measures with fiber strength	+16.16	+.66	+15.50
6 pairs of measures independent of fiber strength	−.11	+.43	−.54
Total, 10 pairs of fiber measures	+16.05	+1.09	+14.96
(1) Estimated variance in yarn strength, 10 pairs of interrelationships	+16.05	+1.09	+14.96
(2) Interactions and residuals, multiple correlation analysis [2]	+14.29	−.93	+15.22
Difference (1)−(2)	+1.76	+2.02	−0.26

[1] Estimated percentage of variance in strength of 22s yarn explainable by the interrelationship existing between each pair of fiber measures was calculated on the basis of the square of the sum of the 2 beta values identified with each pair of factors, multiplied by 100, and multiplied by the coefficient of determination ($\bar{r}^2$) representing the interrelationship for the pair of fiber measures involved, with sign determined as explained in the text.

[2] The value for the interactions and residuals, as evaluated by each multiple correlation analysis, represents the difference between the total variance in strength of 22s yarn explained by the 5 cotton fiber measures ($\bar{R}^2 \times 100$) minus the sum of the respective beta values squared × 100.

TABLE 21.—*Estimated percentages of variance in skein strength of 22s carded yarn explained by 10 pairs of interrelationships representing 5 fiber measures including alternative measures of fiber strength, and total interactions and residuals evaluated by multiple correlation analysis, for the series of 173 long staple American upland cottons, crop years 1954–56*

Statistical item	Values from analysis, including fiber strength at— ⅛-in. gauge (1)	0 gauge (2)	Difference (1−2)
	Percent	*Percent*	*Percent*
Fiber interrelationships toward yarn strength ($\bar{r}^2 \times 100$) for—			
4 respective measures with fiber strength	+75.42	+30.98	+44.44
6 pairs of measures independent of fiber strength	+33.59	+33.59	.00
Total, 10 pairs of fiber measures	+109.01	+64.57	+44.44
Estimated variance in yarn strength[1] due to interrelationships for—			
4 respective measures with fiber strength	+39.70	+13.73	+25.97
6 pairs of measures independent of fiber strength	+5.15	+11.57	−6.42
Total, 10 pairs of fiber measures	+44.85	+25.30	+19.55
(1) Estimated variance in yarn strength, 10 pairs of interrelationships	+44.85	+25.30	+19.55
(2) Interactions and residuals, multiple correlation analysis[2]	+40.30	+33.97	+6.33
Difference (1)−(2)	+4.55	−8.67	+13.22

[1] Estimated percentage of variance in strength of 22s yarn explainable by the interrelationship existing between each pair of fiber measures was calculated on the basis of the square of the sum of the 2 beta values identified with each pair of factors, multiplied by 100, and multiplied by the coefficient of determination ($\bar{r}^2$) representing the interrelationship for the pair of fiber measures involved, with sign determined as explained in the text.

[2] The value for the interactions and residuals, as evaluated by each multiple correlation analysis, represents the difference between the total variance in strength of 22s yarn explained by the 5 cotton fiber measures ($\bar{R}^2 \times 100$) minus the sum of the respective beta values squared×100.

TABLE 22.—*Summary of coefficients of simple correlation ($\bar{r}$ and $\bar{r}^2 \times 100$) showing the relative gross importance of 5 fiber measures, including fiber strength at ⅛-inch gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative gross importance		
	Rank	Coefficient of correlation ($\bar{r}$)[2]	$\bar{r}^2 \times 100$
81 short cottons:			*Percent*
Fiber strength ⅛-in. gauge	1	+0.653	42.61
Upper half mean length	2	+.337	11.38
Micronaire	3	.000	.00
Grade index	3	.000	.00
Length uniformity ratio	3	.000	.00
Total	----------	.990	53.99
260 medium length cottons:			
Fiber strength ⅛-in. gauge	1	+0.703	49.41
Upper half mean length	2	+.426	18.13
Grade index	3	+.349	12.17
Micronaire	4	−.133*	1.76
Length uniformity ratio	5	+.078*	.60
Total	----------	1.689**	82.07
173 long cottons:			
Fiber strength ⅛-in. gauge	1	+0.836	69.90
Upper half mean length	2	+.722	52.14
Grade index	3	+.538	28.90
Micronaire	4	−.396	15.64
Length uniformity ratio	5	+.325	10.58
Total	----------	2.817**	177.16

[1] Number of lots of cotton represented in each correlation analysis.

[2] The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

TABLE 23.—*Summary of coefficients of simple correlation ($\bar{r}$ and $\bar{r}^2 \times 100$) showing the relative gross importance of 5 fiber measures, including fiber strength at 0 gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative gross importance: Rank	Relative gross importance: Coefficient of correlation ($\bar{r}$)[2]	Relative gross importance: $\bar{r}^2 \times 100$
			Percent
81 short cottons:			
Upper half mean length	1	+0.337	11.38
Fiber strength 0 gauge	2	.000	.00
Micronaire	2	.000	.00
Grade index	2	.000	.00
Length uniformity ratio	2	.000	.00
Total		0.337	11.38
260 medium-length cottons:			
Upper half mean length	1	+0.426	18.13
Grade index	2	+.349	12.17
Fiber strength 0 gauge	3	+.246	6.07
Micronaire	4	−.133*	1.76
Length uniformity ratio	5	+.078*	.60
Total		1.232**	38.73
173 long cottons:			
Upper half mean length	1	+0.722	52.14
Fiber strength 0 gauge	2	+.686	47.07
Grade index	3	+.538	28.90
Micronaire	4	−.396	15.64
Length uniformity ratio	5	+.325	10.58
Total		2.667**	154.33

[1] Number of lots of cotton represented in each correlation analysis.

[2] The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

Table 24.—*Relative gross importance of each of 5 fiber measures toward skein strength of 22s carded yarn, including alternative fiber strength measures, as evaluated by coefficients of determination ($\bar{r}^2 \times 100$) from simple correlation analyses, for 3 series of selected American upland cottons, crop years 1954–57*

Fiber measure, number of observations,[1] and length series	$\bar{r}^2 \times 100$ values, including fiber strength at—		Difference
	⅛-in. gauge [2] (1)	0 gauge [2] (2)	(1−2)
	Percent	*Percent*	*Percent*
Fiber strength:			
81 short cottons	(1) 42.61	(2) 0.00	+42.61
260 medium length cottons	(1) 49.41	(3) 6.07	+43.34
173 long cottons	(1) 69.90	(2) 47.07	+22.83
Upper half mean length:			
81 short cottons	(2) 11.38	(1) 11.38	0
260 medium length cottons	(2) 18.13	(1) 18.13	0
173 long cottons	(2) 52.14	(1) 52.14	0
Micronaire:			
81 short cottons	(3) 0	(2) 0	0
260 medium length cottons	(4) 1.76*	(4) 1.76*	0
173 long cottons	(4) 15.64	(4) 15.64	0
Length uniformity ratio:			
81 short cottons	(3) 0	(2) 0	0
260 medium length cottons	(5) .60*	(5) .60*	0
173 long cottons	(5) 10.58	(5) 10.58	0
Grade index:			
81 short cottons	(3) 0	(2) 0	0
260 medium length cottons	(3) 12.17	(2) 12.17	0
173 long cottons	(3) 28.90	(3) 28.90	0
Total, 5 measures:			
81 short cottons	53.99	11.38	+42.61
260 medium length cottons	82.07	38.73	+43.34
173 long cottons	177.16	154.33	+22.83

[1] Number of lots of cotton represented in each correlation analysis.

[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5 factors, toward skein strength of 22s carded yarn.

*Corresponding coefficient of simple correlation ($\bar{r}$) was statistically insignificant, being less than 3 times its standard error.

TABLE 25.—*Parallel values from simple and multiple correlation analyses showing the relative gross and net importance of 5 fiber measures, including fiber strength at ⅛-inch gauge, toward skein strength of 22s carded yarn, for three series of American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Variance in yarn strength evaluated by—		Difference
	$\bar{r}^2 \times 100$ (gross) [2] (1)	$Beta^2 \times 100$ (net) [2] (2)	(1−2)
	Percent	*Percent*	*Percent*
81 short cottons:			
Fiber strength ⅛-in. gauge	(1) 42.61	(1) 40.07	+2.54
Upper half mean length	(2) 11.38	(2) 12.32	−.94
Grade index	(3) 0	(3) 3.88*	−3.88
Micronaire	(3) 0	(4) 1.06*	−1.06
Length uniformity ratio	(3) 0	(5) .11*	−.11
Total	53.99	57.44	−3.45
260 medium length cottons:			
Fiber strength ⅛-in. gauge	(1) 49.41	(1) 32.38	+17.03
Upper half mean length	(2) 18.13	(4) 2.37	+15.76
Grade index	(3) 12.17	(2) 5.52	+6.65
Micronaire	(4) 1.76*	(3) 3.28	−1.52
Length uniformity ratio	(5) .60*	(5) .07*	+.53
Total	82.07	43.62	+38.45
173 long cottons:			
Fiber strength ⅛-in. gauge	(1) 69.90	(1) 27.98	+41.92
Upper half mean length	(2) 52.14	(2) 5.11	+47.03
Grade index	(3) 28.90	(4) 3.57	+25.33
Micronaire	(4) 15.64	(3) 4.37	+11.27
Length uniformity ratio	(5) 10.58	(5) .69*	+9.89
Total	177.16	41.72	+135.44

[1] Number of lots of cotton represented in each correlation analysis.
[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5, toward skein strength of 22s carded yarn.

*Corresponding coefficient of simple correlation or beta coefficient from multiple correlation analysis was statistically insignificant, being less than 3 times its standard error.

TABLE 26.—*Parallel values from simple and multiple correlation analyses showing the relative gross and net importance of 5 fiber measures, including fiber strength at 0 gauge, toward skein strength of 22s carded yarn, for 3 series of American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Variance in yarn strength evaluated by— $\bar{r}^2 \times 100$ (gross) [2] (1)	Variance in yarn strength evaluated by— Beta$^2 \times 100$ (net) [2] (2)	Difference (1−2)
81 short cottons:	*Percent*	*Percent*	*Percent*
Upper half mean length	(1) 11.38	(1) 20.61	−9.23
Fiber strength 0 gauge	(2) 0	(2) 7.56*	−7.56
Micronaire	(2) 0	(3) 6.76*	−6.76
Grade index	(2) 0	(4) 3.72*	−3.72
Length uniformity ratio	(2) 0	(5) 3.28*	−3.28
Total	11.38	41.93	−30.55
260 medium length cottons:			
Upper half mean length	(1) 18.13	(1) 19.45	−1.32
Grade index	(2) 12.17	(2) 13.25	−1.08
Fiber strength 0 gauge	(3) 6.07	(3) 5.48	+.59
Micronaire	(4) 1.76*	(4) 3.39	−1.63
Length uniformity ratio	(5) .60*	(5) .48*	+.12
Total	38.73	42.05	−3.32
173 long cottons:			
Upper half mean length	(1) 52.14	(1) 21.25	+30.89
Fiber strength 0 gauge	(2) 47.07	(2) 20.98	+26.09
Grade index	(3) 28.90	(4) 1.37	+27.53
Micronaire	(4) 15.64	(3) 5.02	+10.62
Length uniformity ratio	(5) 10.58	(5) 1.04*	+9.54
Total	154.33	49.66	+104.67

[1] Number of lots of cotton represented in each correlation analysis.

[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5, toward skein strength of 22s carded yarn.

*Corresponding coefficient of simple correlation or beta coefficient from multiple correlation analysis was statistically insignificant, being less than 3 times its standard error.

TABLE 27.—*Differences between corresponding pairs of $\bar{r}^2\times 100$ and beta$^2\times 100$ values, as obtained from simple and multiple correlation analyses, respectively, representing 5 fiber measures including alternative measures of fiber strength, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measures	$\bar{r}^2\times 100$—beta^2 $\times 100$ from analysis, including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
	Percent	*Percent*	*Percent*
81 short cottons:			
Fiber strength	+2.54	−7.56	+10.10
Upper half mean length	−.94	−9.23	+8.29
Grade index	−3.88	−3.72	−.16
Micronaire	−1.06	−6.76	+5.70
Length uniformity ratio	−.11	−3.28	+3.17
Total	−3.45	−30.55	+27.10
260 medium length cottons:			
Fiber strength	+17.03	+.59	+16.44
Upper half mean length	+15.76	−1.32	+17.08
Grade index	+6.65	−1.08	+7.73
Micronaire	−1.52	−1.63	+.11
Length uniformity ratio	+.53	+.12	+.41
Total	+38.45	−3.32	+41.77
173 long cottons:			
Fiber strength	+41.92	+26.09	+15.83
Upper half mean length	+47.03	+30.89	+16.14
Grade index	+25.33	+27.53	−2.20
Micronaire	+11.27	+10.62	+.65
Length uniformity ratio	+9.89	+9.54	+.35
Total	+135.44	+104.67	+30.77

[1] Number of lots of cotton represented in each correlation analysis.

TABLE 28.—*Summary of coefficients of partial correlation and of partial determination ×100 showing the relative net importance of 5 fiber measures, including fiber strength at ⅛-inch gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative net importance		
	Rank	Partial $\bar{R}$†	Partial $\bar{R}^2 \times 100$
81 short cottons:			*Percent*
Fiber strength at ⅛-in. gauge	1	+0.686	47.06
Upper half mean length	2	+.451	20.34
Grade index	3	+.251*	6.30
Micronaire	4	−.134*	1.80
Length uniformity ratio	5	+.047*	.22
Total		1.569**	75.72
260 medium length cottons:			
Fiber strength at ⅛-in. gauge	1	+0.586	34.34
Grade index	2	+.315	9.92
Micronaire	3	−.260	6.76
Upper half mean length	4	+.198	3.92
Length uniformity ratio	5	+.039*	.15
Total		1.398**	55.09
173 long cottons:			
Fiber strength at ⅛-in. gauge	1	+0.670	44.89
Micronaire	2	−.404	16.32
Upper half mean length	3	+.364	13.25
Grade index	4	+.362	13.10
Length uniformity ratio	5	+.170*	2.89
Total		1.970**	90.45

[1] Number of lots of cotton represented in each correlation analysis.

†The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

TABLE 29.—*Summary of coefficients of partial correlation and of partial determination ×100 showing the relative net importance of 5 fiber measures, including fiber strength at 0 gauge, toward skein strength of 22s carded yarn, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Relative net importance		
	Rank	Partial $\overline{R}$†	Partial $\overline{R}^2 \times 100$
81 short cottons:			*Percent*
Upper half mean length	1	+0.434	18.84
Fiber strength at 0 gauge	2	+.211*	4.45
Length uniformity ratio	3	+.195*	3.80
Micronaire	4	−.194*	3.76
Grade index	5	+.186*	3.46
Total		1.220**	34.31
260 medium length cottons:			
Upper half mean length	1	+0.494	24.40
Grade index	2	+.413	17.06
Fiber strength at 0 gauge	3	+.286	8.18
Micronaire	4	−.225	5.06
Length uniformity ratio	5	+.087*	.76
Total		1.505**	55.46
173 long cottons:			
Fiber strength at 0 gauge	1	+0.705	49.70
Upper half mean length	2	+.687	47.20
Micronaire	3	−.446	19.89
Grade index	4	+.235	5.52
Length uniformity ratio	5	+.218*	4.75
Total		2.291**	127.06

[1] Number of lots of cotton represented in each correlation analysis.

†The sign indicates the direction of the contribution of the factor toward yarn strength.

*Statistically insignificant, being less than 3 times its standard error.

**Addition was made without regard to signs.

TABLE 30.—*Relative net importance of each of 5 fiber measures toward skein strength of 22s carded yarn, as evaluated by coefficients of partial determination ×100 from analyses including alternative fiber strength measures, for 3 series of selected American upland cottons, crop years 1954–57*

Fiber measure, number of observations,[1] and length series	Partial $\bar{R}^2 \times 100$ from analysis, including fiber strength at—		Difference
	⅛-in. gauge [2] (1)	0 gauge [2] (2)	(1−2)
	Percent	*Percent*	*Percent*
Fiber strength:			
81 short cottons	(1) 47.06	(2) 4.45*	+42.61
260 medium length cottons	(1) 34.34	(3) 8.18	+26.16
173 long cottons	(1) 44.89	(1) 49.70	−4.81
Upper half mean length:			
81 short cottons	(2) 20.34	(1) 18.84	+1.50
260 medium length cottons	(4) 3.92	(1) 24.40	−20.48
173 long cottons	(3) 13.25	(2) 47.20	−33.95
Micronaire:			
81 short cottons	(4) 1.80*	(4) 3.76*	−1.96
260 medium length cottons	(3) 6.76	(4) 5.06	+1.70
173 long cottons	(2) 16.32	(3) 19.89	−3.57
Length uniformity ratio:			
81 short cottons	(5) .22*	(3) 3.80*	−3.58
260 medium length cottons	(5) .15*	(5) .76*	−.61
173 long cottons	(5) 2.89*	(5) 4.75*	−1.86
Grade index:			
81 short cottons	(3) 6.30*	(5) 3.46*	+2.84
260 medium length cottons	(2) 9.92	(2) 17.06	−7.14
173 long cottons	(4) 13.10	(4) 5.52	+7.58
Total, 5 measures:			
81 short cottons	75.72	34.31	+41.41
260 medium length cottons	55.09	55.46	−.37
173 long cottons	90.45	127.06	−36.61

[1] Number of lots of cotton represented in each correlation analysis.
[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5 factors, toward skein strength of 22s carded yarn.

*Corresponding coefficient of partial correlation was statistically insignificant, being less than 3 times its standard error.

TABLE 31.—*Relative net importance of 5 fiber measures, including fiber strength at ⅛-inch gauge, toward skein strength of 22s carded yarn, as evaluated by partial $\bar{R}^2 \times 100$ values and by $beta^2 \times 100$ values from multiple correlation analyses, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Variance in yarn strength evaluated by—		Difference
	Partial $\bar{R}^2 \times 100$[2] (1)	$Beta^2 \times 100$[2] (2)	(1−2)
81 short cottons:	*Percent*	*Percent*	*Percent*
Fiber strength ⅛-in. gauge	(1) 47.06	(1) 40.07	+6.99
Upper half mean length	(2) 20.34	(2) 12.32	+8.02
Grade index	(3) 6.30*	(3) 3.88*	+2.42
Micronaire	(4) 1.80*	(4) 1.06*	+.74
Length uniformity rario	(5) .22*	(5) .11*	+.11
Total	75.72	57.44	+18.28
260 medium length cottons:			
Fiber strength ⅛-in. gauge	(1) 34.34	(1) 32.38	+1.96
Grade index	(2) 9.92	(2) 5.52	+4.40
Micronaire	(3) 6.76	(3) 3.28	+3.48
Upper half mean length	(4) 3.92	(4) 2.37	+1.55
Length uniformity ratio	(5) .15*	(5) .07*	+.08
Total	55.09	43.62	+11.47
173 long cottons:			
Fiber strength ⅛-in. gauge	(1) 44.89	(1) 27.98	+16.91
Micronaire	(2) 16.32	(3) 4.37	+11.95
Upper half mean length	(3) 13.25	(2) 5.11	+8.14
Grade index	(4) 13.10	(4) 3.57	+9.53
Length uniformity ratio	(5) 2.89*	(5) .69*	+2.20
Total	90.45	41.72	+48.73

[1] Number of lots of cotton represented in each correlation analysis.

[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5, toward skein strength of 22s carded yarn.

*Corresponding coefficient of partial correlation or beta coefficient from multiple correlation analysis was statistically insignificant, being less than 3 times its standard error.

TABLE 32.—*Relative net importance of 5 fiber measures, including fiber strength at 0 gauge, toward skein strength of 22s carded yarn, as evaluated by partial $\bar{R}^2 \times 100$ values and by beta$^2 \times 100$ values from multiple correlation analyses, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Variance in yarn strength evaluated by—		Difference
	Partial $\bar{R}^2 \times 100$ [2] (1)	Beta$^2 \times 100$ [2] (2)	(1−2)
	Percent	*Percent*	*Percent*
81 short cottons:			
Upper half mean length	(1) 18.84	(1) 20.61	−1.77
Fiber strength 0 gauge	(2) 4.45*	(2) 7.56*	−3.11
Length uniformity ratio	(3) 3.80*	(5) 3.28*	+.52
Micronaire	(4) 3.76*	(3) 6.76*	−3.00
Grade index	(5) 3.46*	(4) 3.72*	−.26
Total	34.31	41.93	−7.62
260 medium length cottons:			
Upper half mean length	(1) 24.40	(1) 19.45	+4.95
Grade index	(2) 17.06	(2) 13.25	+3.81
Fiber strength 0 gauge	(3) 8.18	(3) 5.48	+2.70
Micronaire	(4) 5.06	(4) 3.39	+1.67
Length uniformity ratio	(5) .76*	(5) .48*	+.28
Total	55.46	42.05	+13.41
173 long cottons:			
Fiber strength 0 gauge	(1) 49.70	(2) 20.98	+28.72
Upper half mean length	(2) 47.20	(1) 21.25	+25.95
Micronaire	(3) 19.89	(3) 5.02	+14.87
Grade index	(4) 5.52	(4) 1.37	+4.15
Length uniformity ratio	(5) 4.75*	(5) 1.04*	+3.71
Total	127.06	49.66	+77.40

[1] Number of lots of cotton represented in each correlation analysis.

[2] Number in parentheses indicates the rank of importance of the fiber measure, among 5, toward skein strength of 22s carded yarn.

*Corresponding coefficient of partial correlation or beta coefficient from multiple correlation analysis was statistically insignificant, being less than 3 times its standard error.

TABLE 33.—*Differences between respective pairs of partial $\overline{R}^2 \times 100$ values and beta$^2 \times 100$ values from analyses with 5 fiber measures and skein strength of 22s carded yarn, including alternative measures of fiber strength, for 3 series of selected American upland cottons, crop years 1954–57*

Number of observations,[1] length series, and fiber measure	Partial $\overline{R}^2$ x 100—beta^2 ×100 from analysis, including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
81 short cottons:	*Percent*	*Percent*	*Percent*
Fiber strength	+6.99	−3.11	+10.10
Upper half mean length	+8.02	−1.77	+9.79
Grade index	+2.42	−.26	+2.68
Micronaire	+.74	−3.00	+3.74
Length uniformity ratio	+.11	+.52	−.41
Total	+18.28	−7.62	+25.90
260 medium-length cottons:			
Fiber strength	+1.96	+2.70	−0.74
Grade index	+4.40	+3.81	+.59
Micronaire	+3.48	+1.67	+1.81
Upper half mean length	+1.55	+4.95	−3.40
Length uniformity ratio	+.08	+.28	−.20
Total	+11.47	+13.41	−1.94
173 long cottons:			
Fiber strength	+16.91	+28.72	−11.81
Micronaire	+11.95	+14.87	−2.92
Upper half mean length	+8.14	+25.95	−17.81
Grade index	+9.53	+4.15	+5.38
Length uniformity ratio	+2.20	+3.71	−1.51
Total	+48.73	+77.40	−28.67

[1] Number of lots of cotton represented in each correlation analysis.

TABLE 34.—*Summary of variance explained in skein strength of 22s carded yarn by interactions and residuals associated with 10 pairs of 5 fiber measures, including alternative measures of fiber strength, as evaluated by 5 different combinations of values from multiple and simple correlation analyses, representing 3 series of selected American upland cottons, crop years 1954–57*

Interactions and residuals	Variance in yarn strength for series of—		
	81 short cottons, 1954–57	260 medium length cottons, 1954	173 long cottons, 1954–56
Analyses, including fiber strength at ⅛-in. gauge:	*Percent*	*Percent*	*Percent*
Estimate from fiber interrelationships [1]	−0.74	+10.44	+26.82
Do [2]	−1.84	+16.05	+44.85
$\bar{R}^2 \times 100 -$ sum of 5 $\text{beta}^2 \times 100$	−.61	+14.29	+40.30
½ (sum of $5\bar{r}^2 \times 100 -$ sum of 5 $\text{beta}^2 \times 100$) [3]	−1.73	+19.23	+67.72
Sum of $5\bar{r}^2 \times 100 - \bar{R}^2 \times 100$	−2.84	+24.16	+95.14
Mean	−1.55	+16.83	+54.97
Analyses, including fiber strength at 0 gauge:			
Estimate from fiber interrelationships [1]	−10.20	+0.73	+15.79
Do [2]	−19.85	+1.09	+25.30
$\bar{R}^2 \times 100 -$ sum of 5 $\text{beta}^2 \times 100$	−19.79	−.93	+33.97
½ (sum of $5\bar{r}^2 \times 100 -$ sum of 5 $\text{beta}^2 \times 100$) [3]	−15.28	−1.66	+52.34
Sum of $5\bar{r}^2 \times 100 - \bar{R}^2 \times 100$	−10.76	−2.39	+70.70
Mean	−15.18	−0.63	+39.62

[1] The sum of the squares of the 2 respective beta values identified with each of the 10 pairs of fiber measures was used as the basis of calculation.

[2] The square of the sum of the 2 beta values identified with each of the 10 pairs of fiber measures was used as the basis of calculation.

[3] As the sum of $5\bar{r}^2$ represents 10 duplicate pairs of the 5 fiber measures (5×4), division of the difference value by 2 is necessary to represent 10 individual pairs of the fiber measures and give a value comparable with the other values listed.

TABLE 35.—*Summary of variance explained in skein strength of 22s carded yarn by interactions and residuals associated with 10 pairs of 5 fiber measures, including alternative measures of fiber strength, as evaluated by 5 different methods and presented collectively for each of the 3 series of selected American upland cottons, crop years 1954–57*

Number of observations, length series, and interactions and residuals	Variance in yarn strength, analyses including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
81 short cottons:	*Percent*	*Percent*	*Percent*
Estimate from fiber interrelationships[1]	−0.74	−10.20	+9.46
Do.[2]	−1.84	−19.85	+18.01
$\bar{R}^2\times100$—sum of 5 $beta^2\times100$	−.61	−19.79	+19.18
½ (sum of $5\bar{r}^2\times100$—sum of 5 $beta^2\times100$)[3]	−1.73	−15.28	+13.55
Sum of 5 $\bar{r}^2\times100$—$\bar{R}^2\times100$	−2.84	−10.76	+7.92
Mean	−1.55	−15.18	+13.63
260 medium length cottons:			
Estimate from fiber interrelationships[1]	+10.44	+0.73	+9.71
Do.[2]	+16.05	+1.09	+14.96
$\bar{R}^2\times100$—sum of 5 $beta^2\times100$	+14.29	−.93	+15.22
½ (sum of $5\bar{r}^2\times100$—sum of 5 $beta^2\times100$)[3]	+19.23	−1.66	+20.89
Sum of 5 $\bar{r}^2\times100$—$\bar{R}^2\times100$	+24.16	−2.39	+26.55
Mean	+16.83	−0.63	+17.46
173 long cottons:			
Estimate from fiber interrelationships[1]	+26.82	+15.79	+11.03
Do.[2]	+44.85	+25.30	+19.55
$\bar{R}^2\times100$—sum of 5 $beta^2\times100$	+40.30	+33.97	+6.33
½ (sum of $5\bar{r}^2\times100$—sum of 5 $beta^2\times100$)[3]	+67.72	+52.34	+15.38
Sum of 5 $\bar{r}^2\times100$—$\bar{R}^2\times100$	+95.14	+70.70	+24.44
Mean	+54.97	+39.62	+15.35

[1] The sum of the squares of the 2 respective beta values identified with each of the 10 pairs of fiber measures was used as the basis of calculation.

[2] The square of the sum of the 2 beta values identified with each of the 10 pairs of fiber measures was used as the basis of the calculation.

[3] As the sum of $5\bar{r}^2$ represents 10 duplicate pairs of the 5 fiber measures (5×4), division of the difference value by 2 is necessary to represent 10 individual pairs of the fiber measures and give a value comparable with the other values listed.

TABLE 36.—*Summary of variance explained in skein strength of 22s carded yarn by interactions and residuals associated with 10 pairs of 5 fiber measures, including alternative measures of fiber strength, as evaluated by the 5 different methods and presented individually for the 3 series of selected American upland cottons, crop years 1954–57*

Interactions and residuals	Variance in yarn strength, analyses including fiber strength at—		Difference
	⅛-in. gauge (1)	0 gauge (2)	(1−2)
Estimate from fiber interrelationships: [1]	*Percent*	*Percent*	*Percent*
81 short cottons	−0.74	−10.20	+9.46
260 medium length cottons	+10.44	+.73	+9.71
173 long cottons	+26.82	+15.79	+11.03
Estimate from fiber interrelationships: [2]			
81 short cottons	−1.84	−19.85	+18.01
260 medium length cottons	+16.05	+1.09	+14.96
173 long cottons	+44.85	+25.30	+19.55
$\overline{R}^2 \times 100$—sum of 5 $beta^2 \times 100$:			
81 short cottons	−.61	−19.79	+19.18
260 medium length cottons	+14.29	−.93	+15.22
173 long cottons	+40.30	+33.97	+6.33
½ (sum of $5\overline{r}^2 \times 100$—sum of 5 $beta^2 \times 100$): [3]			
81 short cottons	−1.73	−15.28	+13.55
260 medium length cottons	+19.23	−1.66	+20.89
173 long cottons	+67.72	+52.34	+15.38
Sum of $5\overline{r}^2 \times 100 - \overline{R}^2 \times 100$:			
81 short cottons	−2.84	−10.76	+7.92
260 medium length cottons	+24.16	−2.39	+26.55
173 long cottons	+95.14	+70.70	+24.44

[1] The sum of the squares of the 2 respective beta values identified with each of the 10 pairs of fiber measures was used as the basis of calculation.

[2] The square of the sum of the 2 beta values identified with each of the 10 pairs of fiber measures was used as the basis of calculation.

[3] As the sum of $5\overline{r}^2$ represents 10 duplicate pairs of the 5 fiber measures (5×4), division of the difference value by 2 is necessary to represent 10 individual pairs of the fiber measures and give a value comparable with the other values listed.

TABLE 37.—*Summary of ratio values, fiber strength at 1/8-inch gauge/fiber strength at 0 gauge, for 6 series of American upland cottons and 1 series of American-Egyptian cottons selected to represent different staple-length levels and ranges, crop years 1954–57*

Series of cottons	Lots of cotton	Fiber strength ratio: 1/8-in. gauge/0 gauge			
		Mean	Maximum	Minimum	Range
American upland:					
All cottons in the study:	*Number*				
Short [1]	81	1.18	1.45	0.90	0.55
Medium length [2]	260	1.19	1.39	.96	.43
Long [3]	173	1.29	1.47	1.10	.37
Selected cottons:					
Short [4]	59	1.18	1.45	.97	.48
Medium length [5]	71	1.25	1.42	.90	.52
Long [6]	83	1.33	1.47	1.13	.34
Short cottons:					
Entire series [1]	81	1.18	1.45	.90	.55
Selected series [4]	59	1.18	1.45	.97	.48
Medium length cottons:					
Entire series [2]	260	1.19	1.39	.96	.43
Selected series [5]	71	1.25	1.42	.90	.52
Long cottons:					
Entire series [3]	173	1.29	1.47	1.10	.37
Selected series [6]	83	1.33	1.47	1.13	.34
American-Egyptian, extra long [7]	57	1.56	1.65	1.41	.24

[1] Staple length 13/16 in. through 1 1/32 in., range 7/32 in., mean 15/16 in.
[2] Staple length 7/8 in. through 1 1/8 in., range 1/4 in., mean 1 1/32 in.
[3] Staple length 1 in. through 1 1/4 in., range 1/4 in., mean 1 3/32+ in.
[4] Staple length 13/16 in. through 15/16 in., range 1/8 in., mean 29/32 in.
[5] Staple length 31/32 in. through 1 1/16 in., range 3/32 in., mean 1 1/32 in.
[6] Staple length 1 1/8 in. through 1 1/4 in., range 1/8 in., mean 1 5/32 in.
[7] Staple length 1 3/8 in. through 1 1/2 in., range 1/8 in., mean 1 7/16 in.

TABLE 38.—*Summary of ratio values, fiber strength at 1/8-inch gauge/fiber strength at 0 gauge, by variety, for 3 series of American upland cottons and 1 series of American-Egyptian cottons representing different staple-length levels, crop years 1954–57*

Growth of cotton, level of staple length, and variety	Lots of cotton	Fiber strength ratio: 1/8-in. gauge/0 gauge			
		Mean	Maximum	Minimum	Range
American upland:					
Short:	*Number*				
Rowden	15	1.06	1.19	0.90	0.29
Hibred	6	1.09	1.17	.97	.20
Western Stormproof	12	1.15	1.26	1.06	.20
Lockett SP–1, SF–1, 88	14	1.18	1.33	1.04	.29
Paymaster 54, 54 B, 101	18	1.32	1.45	1.21	.24
Medium length:					
Coker 100 W, 124	15	1.25	1.36	1.16	.20
Deltapine 15	9	1.26	1.34	1.18	.16
Delfos 9169	22	1.26	1.41	1.10	.31
Long: Acala 1517 C	69	1.33	1.47	1.16	.31
American Egyptian: extra long:					
Pima 32	6	1.47	1.53	1.41	.12
Pima S–1	51	1.57	1.65	1.44	.21

TABLE 39.—*Summary of ratio values, fiber strength at ⅛-inch gauge/fiber strength at 0 gauge, by variety, for 3 series of American upland cottons and 1 series of American-Egyptian cottons representing different staple-length levels, crop year 1961*

Growth of cotton, level of staple length, and variety	Lots of cotton	Fiber strength ratio: ⅛-inch gauge/0 gauge			
		Mean	Maximum	Minimum	Range
American upland:					
Short	*Number*				
Parrott	4	1.15	1.17	1.09	0.08
Northern Star	9	1.16	1.21	1.13	.08
Stoneville 62	3	1.19	1.23	1.16	.07
Western Stormproof	25	1.20	1.31	1.10	.21
Lockett 4789	4	1.24	1.26	1.20	.06
Lankart 57	66	1.26	1.41	1.09	.32
Lankart 611	6	1.26	1.30	1.19	.11
Blightmaster	4	1.27	1.29	1.25	.04
TPSA-41	4	1.27	1.32	1.22	.10
Austin	3	1.28	1.32	1.25	.07
Gregg	18	1.29	1.35	1.19	.16
Paymaster	3	1.32	1.35	1.27	.08
Medium length:					
Coker 100	48	1.21	1.39	.99	.40
Dixie King	13	1.21	1.28	1.16	.12
Rex	32	1.23	1.31	1.16	.15
Stardel	3	1.23	1.27	1.19	.08
Stoneville 7	13	1.23	1.30	1.13	.17
Empire	21	1.24	1.38	1.17	.21
Auburn 56	14	1.26	1.34	1.15	.19
Dekalb 220, 108	5	1.26	1.29	1.19	.10
Delfos 9169	17	1.28	1.37	1.18	.19
Deltapine 15	56	1.29	1.41	1.29	.21
Acala 4-42	58	1.30	1.39	1.19	.20
Deltapine Smoothleaf	115	1.30	1.43	1.17	.26
Deltapine TPSA	3	1.30	1.38	1.17	.21
Fox 10	10	1.30	1.39	1.24	.15
Long:					
Acala 1517 BR	4	1.21	1.28	1.15	.13
Acala 1517 C	29	1.33	1.45	1.21	.24
Acala 1517 D	3	1.40	1.47	1.31	.16
Del Cerro	3	1.44	1.50	1.37	.13
American Egyptian; extra long:					
Pima S-1	15	1.55	1.66	1.49	.17
Pima S-2	3	1.59	1.65	1.52	.13

U.S. GOVERNMENT PRINTING OFFICE: 1965